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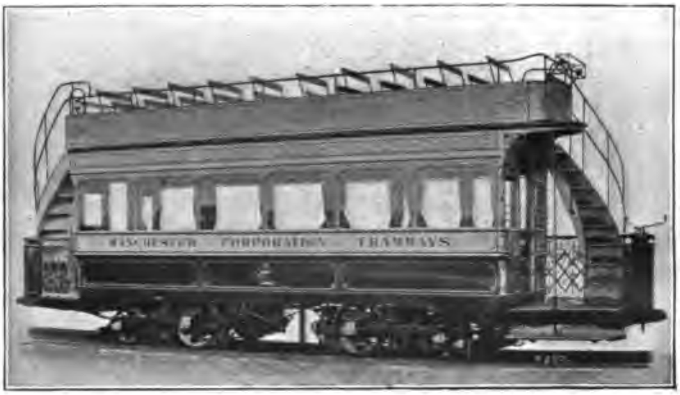

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PRACTICAL CONSTRUCTION

OF

ELECTRIC TRAMWAYS

PRACTICAL CONSTRUCTION
OF
ELECTRIC TRAMWAYS

BY

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PREFACE.

THIS book is intended to be a thoroughly practical work—setting forth the details of the laying out and construction of the permanent way, and the overhead equipment of Electric Tramways. The information given in this first edition is limited to the above branches of practical tramway construction, etc.; but it is intended in the near future to increase the scope of the work, and to introduce some additional information relating chiefly to the slotted conduit system of electric traction, and also to electric street, underground, and elevated railway systems—such, for example, as those in Boston, Mass., U.S.A., which the author considers as being two of the best constructed systems, suiting the local conditions under which they are operated.

There are at the present time some few slotted conduit systems in practical working; time and experience will prove the practical utility and commercial possibilities of this system. As, however, this book is intended to give reliable information only on practically successful working systems, the author does not feel justified at present in setting forth any information relating to this particular branch of the subject.

My thanks are due to Mr. W. G. Rhodes, D.Sc., for giving me permission to use his formula, on pages 6 and 7; and to Mr. H. C. Gunton, for the particulars and details of the Manchester Corporation System, in Chapter VII.; also to Messrs. R. W. Blackwell and Co., Ltd., and Messrs. J. H. Heathman and Co., for loan of blocks illustrating their specialities.

The author has used as books of reference, Merrill's 'Tables, etc., for Street Railway Engineers'; Reckenzaum's 'Electric Traction'; H. Percy Boulnois' 'Carriageways and Footways'; and that excellent weekly periodical, the 'London Electrical Review.' For extracts taken from any of the above, he offers many thanks to the authors, editors, and publishers of the same.

The author will be pleased to receive suggestions and information which will increase the usefulness of this work, also notice of any errors or inaccuracies which may have occurred.

W. R. B.

CONTENTS.

CHAPTER PAGE

I. LAYING OUT THE PERMANENT WAY . . . 1

Gauge and distance apart of tracks—Curves and turnouts—Formula giving relation between radius of curvature and truck-wheel base—Dr. Rhodes' formula—Gradient of track—Length of turnouts—Weight of rails—Joint spacing—Car house curves—Elevation of outside rail—Standard crossovers—Limit of radius of curvature . Pages 1–20

II. ROAD BED FOUNDATION, ETC. 21

Wooden sleeper construction—Cement concrete construction—Dimensions of concrete foundations—Foundation construction—Importance of properly constructed foundation . . . . Pages 21–28

III. LAYING THE RAILS, PLATE LAYING, BONDING, ETC. 29

Rail carriage—Fish-plating and anchor sole-plates used at Lancaster and Brighton—Tie-bars, dimensions of, and distance apart—Copper rail bonds—Bowker flexible rail bonds—Columbia, Chicago and Neptune bonds—Double bonding and cross-bonding—Objects attained by good bonding—Rail filling . . . . Pages 29–36

IV. COMPLETING THE ROADWAY 37

Ballasting of track — wooden sleeper and cement concrete foundation—Paving materials—Wear of pavement—Sizes and shapes of paving setts—Specification of paving—Australian Jarrah and Karri woods—Creosoting of woods—Joint spacing—Dog-toothing—Pitch and cement grouting—Bournemouth pavement—Street paving tools Pages 37–48

CHAPTER PAGE

V. CHOICE OF MATERIALS IN THE LAYING OUT OF CURVES FOR THE OVERHEAD EQUIPMENT . . . 49

Centre line and side line construction — Weight and strain of trolley wire—Staying and strutting of poles—Wood and iron pole construction—Light railways—Rake of poles—Hard drawn copper wire—Silicon-bronze wire—Galvanized iron and steel span wire—Cross wires and guard wires—Planning of curves—Setting of frogs—Distance apart of poles . . . . Pages 49–62

VI. OVERHEAD CONSTRUCTION AND EQUIPMENT . . 63

Planting poles — Guard wires — Tower wagon— Clamp for soldering—Formula for dip and sag—Different pieces of apparatus . . . . . . Pages 63–83

VII. NOTES AND DETAILS ON MATERIALS IN THE CONSTRUCTION AND EQUIPMENT OF VARIOUS TRAMWAY UNDERTAKINGS 84

Manchester — Brighton — Lancaster — Bournemouth — Capetown and Camps Bay—Cardiff—Portsmouth—Salford Great Yarmouth—Wallasey—Glasgow—East Ham—Isle of Thanet—London United Tramways—Weights, sizes and choice of materials . . . Pages 84–98

VIII. TESTING AND MAINTENANCE OF ELECTRIC TRAMWAYS 99

Management of tramways—Duties and qualifications of the General Manager, Traffic Superintendent, Permanent-way Inspector, Overhead Superintendent, Motor men—Hints on maintenance—Choice in type and size of cars—Financial considerations—Possibilities in development of light railways . . . . . . Pages 99–111

INDEX 113

PRACTICAL CONSTRUCTION
OF
ELECTRIC TRAMWAYS.

CHAPTER I.

LAYING OUT THE PERMANENT WAY.

When a town, country, or city has to be equipped with an electric light railway or traction system, the permanent way, before being actually constructed, has to be well laid out. Before being laid out, the gauge and the distance apart of a double track have to be decided upon. The gauge varies (according to circumstances and local conditions) generally from 3 ft. 6 in. to 4 ft. 8½ in.; in nearly every case in good sized towns and cities with moderately wide streets, the gauge adopted is 4 ft. 8½ in. The distance between a double track is usually about 4 feet; if we take 4 ft. 4 in. as the basis of our plans, then the distance from centre to centre of a double track will be 9 feet and ½ inch. (See plan, Fig. 1.)

The laying out of straight track work is comparatively simple, but in the design and planning of curves and complicated layouts, the problem becomes more difficult, and to lay out a good clearance curve where two streets of different widths intersect at different angles involves a good practical knowledge of the laying out of street traction work. Fig. 2 illustrates a "Single-track Plain Curve," and Fig. 3 a "Single-track Right-hand Branch-off."

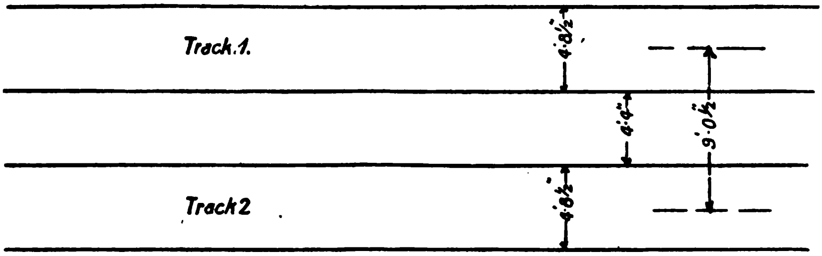


Fig. 1.—Double Track.

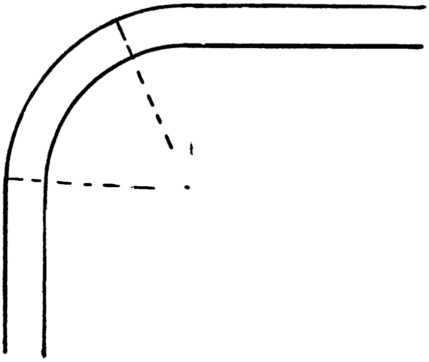


Fig. 2.—Single-track Plain Curve.

In single-track construction, where the cars are running along the same street and track in opposite directions, it becomes necessary at regular intervals along the track to provide means to allow one car to pass another. Provision is made for this by constructing turnouts.

Fig. 4 illustrates a "Side Turnout."

Fig. 5 illustrates a "Diamond Turnout."

Fig. 6 illustrates a "Right-hand Throw-over Turnout."

Fig. 7 illustrates a "Left-hand Throw-over Turnout."

In the laying out of curves, it is not advisable from a practical standpoint to construct them on a radius of less than 40 feet (see Fig. 8); it is only in special and unavoidable cases that the radius of curvature approaches 35 or 30 feet.

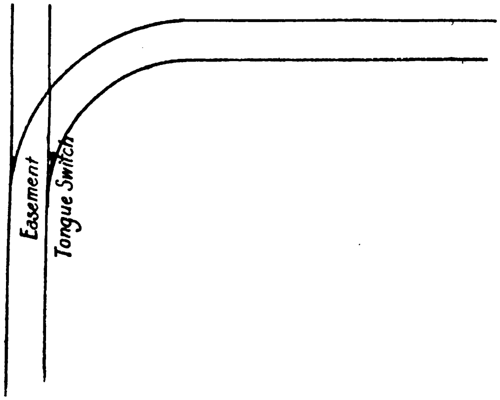


FIG. 3.—SINGLE-TRACK RIGHT-HAND BRANCH-OFF.

The reason for this is the fact that the electric cars are constructed with a certain wheel-base which has practical limits, and if sharp curves occur along a track, it is highly probable that a car going at a moderate speed would not take the curve and would leave the track; and there would also be a grinding action taking place between the flanges of the wheels and the rails,

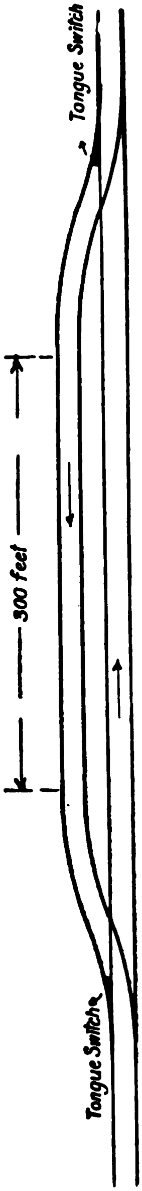


Fig. 4.—Side Turnout.

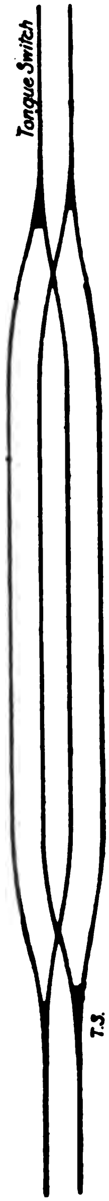


Fig. 5.—Diamond Turnout.

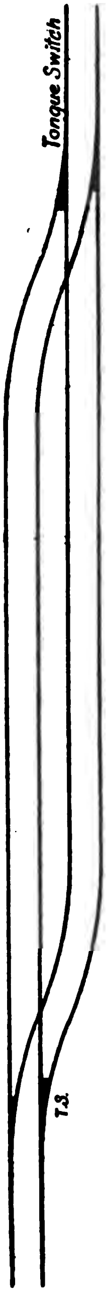


Fig. 6.—Right-hand Throw-over Turnout.

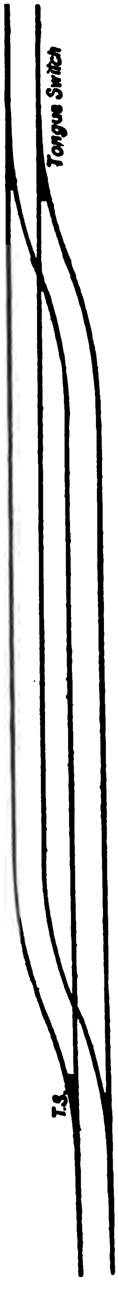


Fig. 7.—Left-hand Throw-over Turnout.

which tends to wear them away and diminish the life of both wheels and track.

If sharp curves occur along the track, the wheel-base of single trucks must be correspondingly short; but there is a practical limit to the shortness of truck wheel bases, which of course limits the radius of curvature of the track.

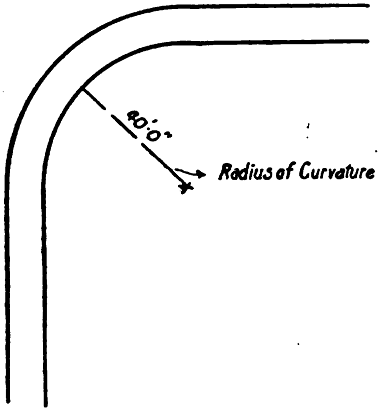


Fig. 8.

If r is the radius in feet of the sharpest curve on the route, t the width of the groove of the rail in inches, and b the wheel base of the truck of the car in feet, then the greatest admissible value of b is given by

$$b = \frac{\sqrt{2\,r\,t}}{3};$$

for example, if $t = 1$ inch, and $r = 75$ feet,

$$b = \frac{\sqrt{2 \times 75 \times 1}}{3} = 7 \text{ feet approximately.}$$

Or, if $t = 1$ inch, and $r = 50$ feet,

$$b = \sqrt{33 \cdot 3}$$

$$= 5 \cdot 78 \text{ feet nearly.}$$

Or again, if $t = 1 \cdot 25$ inch, and $r = 50$ feet,

$$b = 6 \cdot 46 \text{ feet nearly.}$$

The question might be asked: what would be the sharpest curve that a 6-feet wheel base would take without danger of the car leaving the metals or rails, the width of the groove being $1\frac{1}{8}$ inches?

In this case the radius of the curve is given in feet by

$$r = \frac{3\,b^2}{2\,t}$$

$$= \frac{3 \times 36}{2 \times 1 \cdot 125}$$

$$= 48 \text{ feet.}$$

The above example shows the practical relation (and limits) between the wheel base of the truck of the car and the radius of curvature of the track. As regards the gradient of a track, this should not be greater than 1 in 10, and the practical limit seems to be about 1 in 8.

For a heavy car to go up a gradient so great as 1 in 10 demands an enormous quantity of power, consuming a large amount of current, and if the gradient is long as well as steep, the armatures of the motors are greatly heated owing to the large amount of current needed. Going down a steep grade is a great source of danger, since a car may get out of control owing to

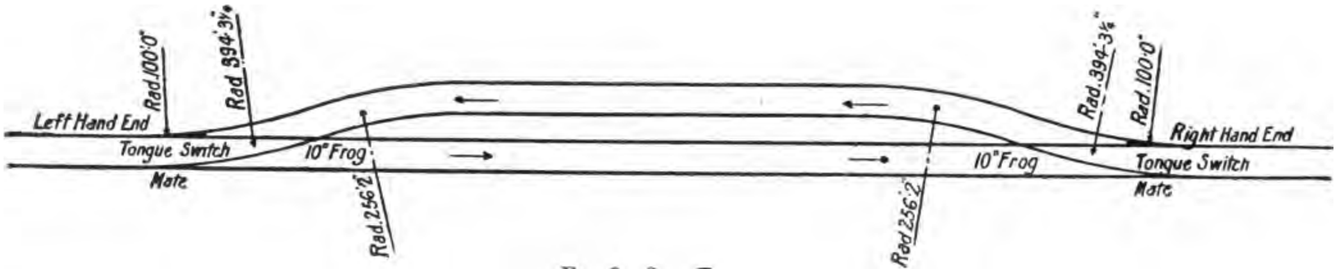


FIG. 9.—SIDE TURNOUT.

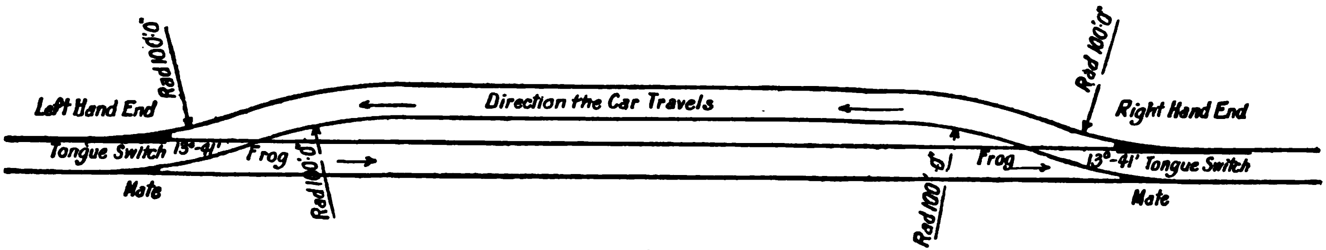


FIG. 10.—SIDE TURNOUT.

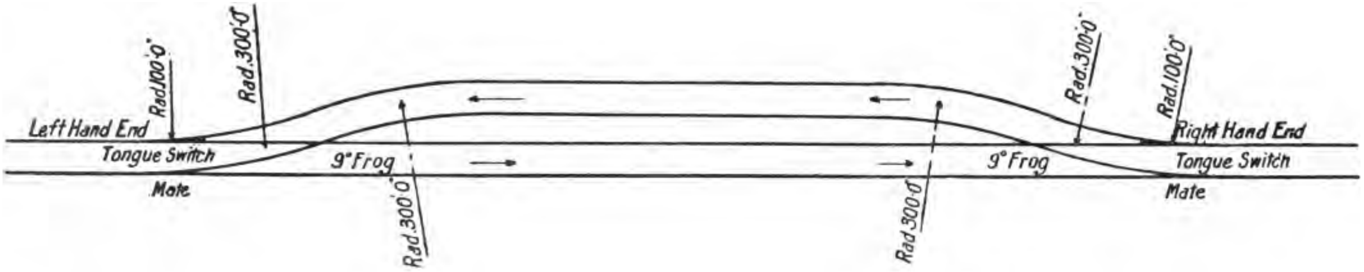


Fig. 11.—Side Turnout.

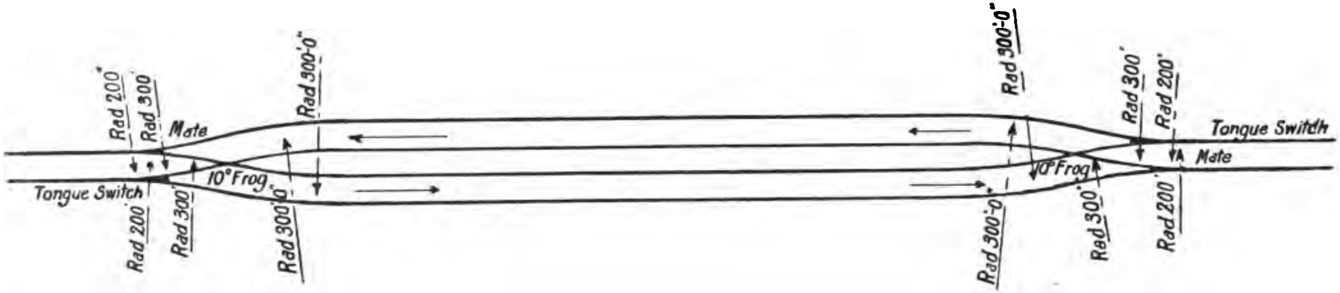


Fig. 12.—Diamond Turnout.

some faulty piece of apparatus in connection with the braking mechanism.

Long and steep gradients, in addition to being very wasteful as regards the power factor, tend to keep the cost of maintenance of the rolling stock high, because on going uphill an undue strain is thrown upon the motors and moving mechanism; and on coming down the hill there is a considerable jolting and vibration of the rolling stock in general, owing to the braking action requisite to keep the car under control.

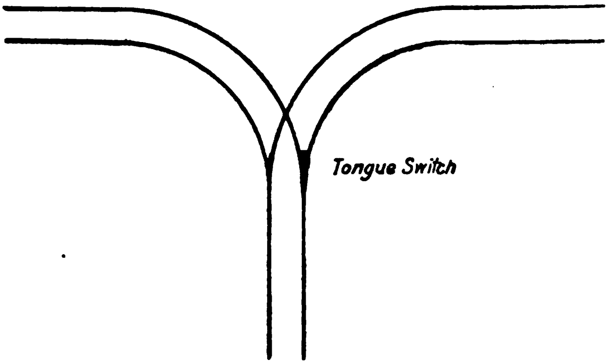


FIG. 13.—PLAIN Y.

For the above reasons it is highly important that the gradients should be kept as low and short as possible.

In Fig. 9 is shown a Standard Turnout for girder rails, giving the various radii, angles of frogs, and showing the tongue-switch and mate.

Fig. 10 shows another turnout with different radii and angles of the frogs.

Fig. 11 is one with different dimensions.

Figs. 9, 10 and 11 are Side Turnouts.

Fig. 12 illustrates a Diamond Turnout.

Fig. 13 illustrates a Plain Y.

Fig. 14 illustrates a Through Y.

Fig. 15 illustrates a Three-part Y, also called a Connected Y.

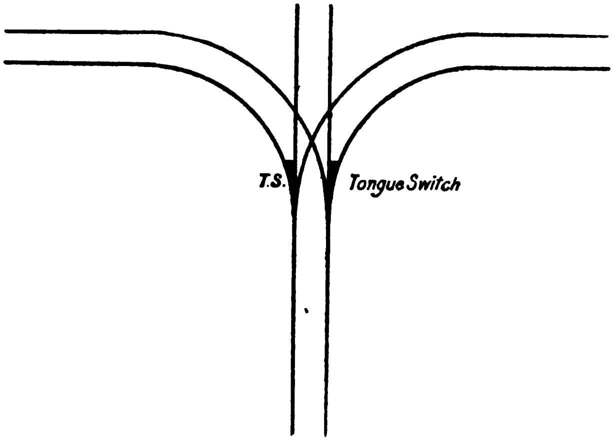


FIG. 14.—THROUGH Y.

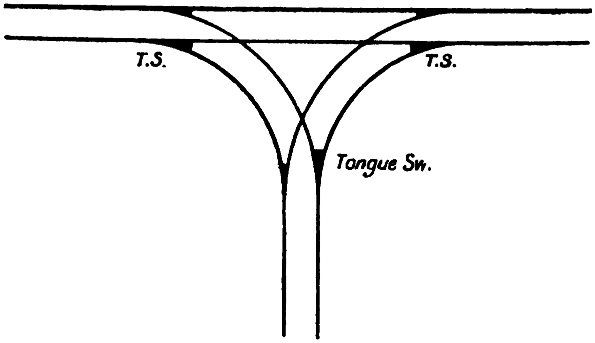


FIG. 15.—THREE-PART Y, ALSO CALLED A CONNECTED Y.

Fig. 16 illustrates a Through-connected Y.

Fig. 17 illustrates a Connecting curve with Crossing.

Fig. 18 illustrates a Double-track Plain Curve.

Fig. 19 illustrates a Double-track Right-hand Branch-off.

Fig. 20 illustrates Car House Curves leading from a Gauntlet Track; used where space is limited.

The length of the turnouts (used with single track), and distance apart, depend somewhat upon the density of the traffic, or, in other words, whether it is a large town or small country traction system. In towns the turnouts

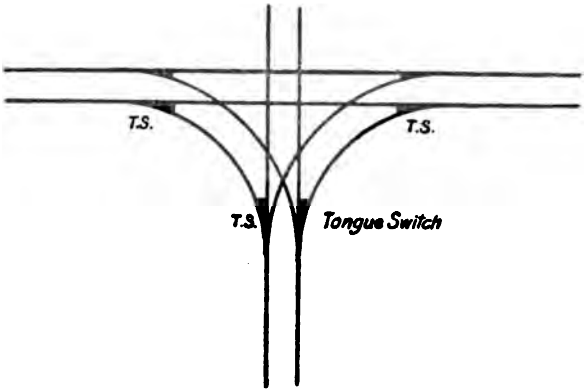


FIG. 16.—THROUGH-CONNECTED Y.

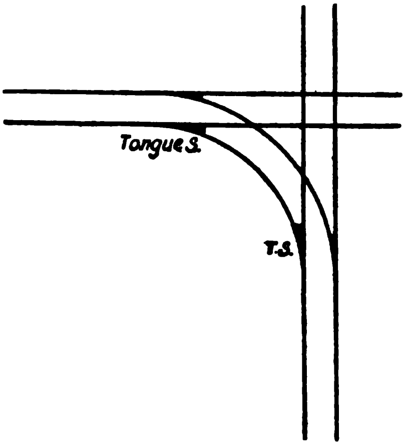


FIG. 17.—CONNECTING CURVE WITH CROSSING.

are generally from 200 to 300 feet long on the straight length (see Fig. 4) and in country places about 200 feet. The reason they are so long is to allow two or more cars to be sided at the same time.

The type of track rail generally used in towns is the "Steel Girder" type, and its weight depends upon local conditions; the weight of the rail is determined by the heaviness of the traffic (not the electric car traffic, but the ordinary street traffic) which passes over it. In large cities and towns, and especially in manufacturing centres, which have heavy street traffic, the rails have to be strong and heavy to withstand it, and the weight of the rail varies from about 100 lb. to 108 lb. per yard.

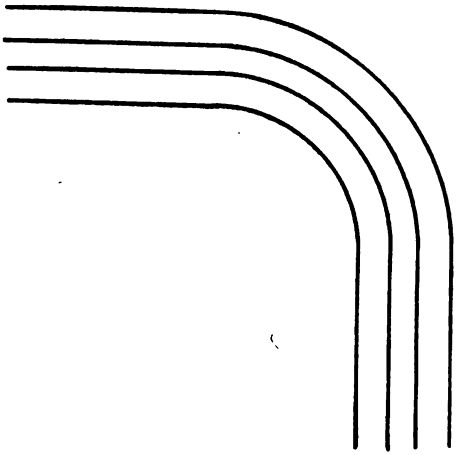


FIG. 18.—DOUBLE-TRACK PLAIN CURVE.

In seaside towns and pleasure resorts (not manufacturing districts), the street traffic is much lighter, and the rails can be used of less weight, generally about 85 lb. to 90 lb. per yard.

As regards joint-spacing, where the rails are laid with the tread flush with the surface of the roadway, and the excavation is filled in immediately after the laying of the rails, the spaces between abutting rails may be omitted. Such work, however, requires the exercise of great care, judgment and experience.

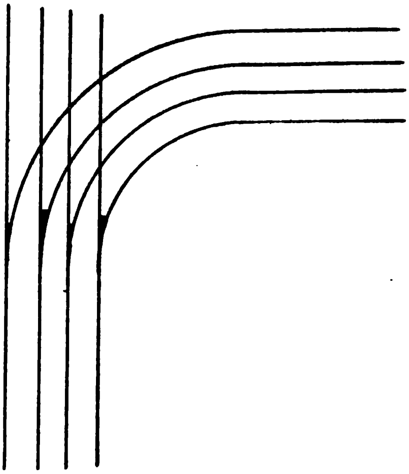


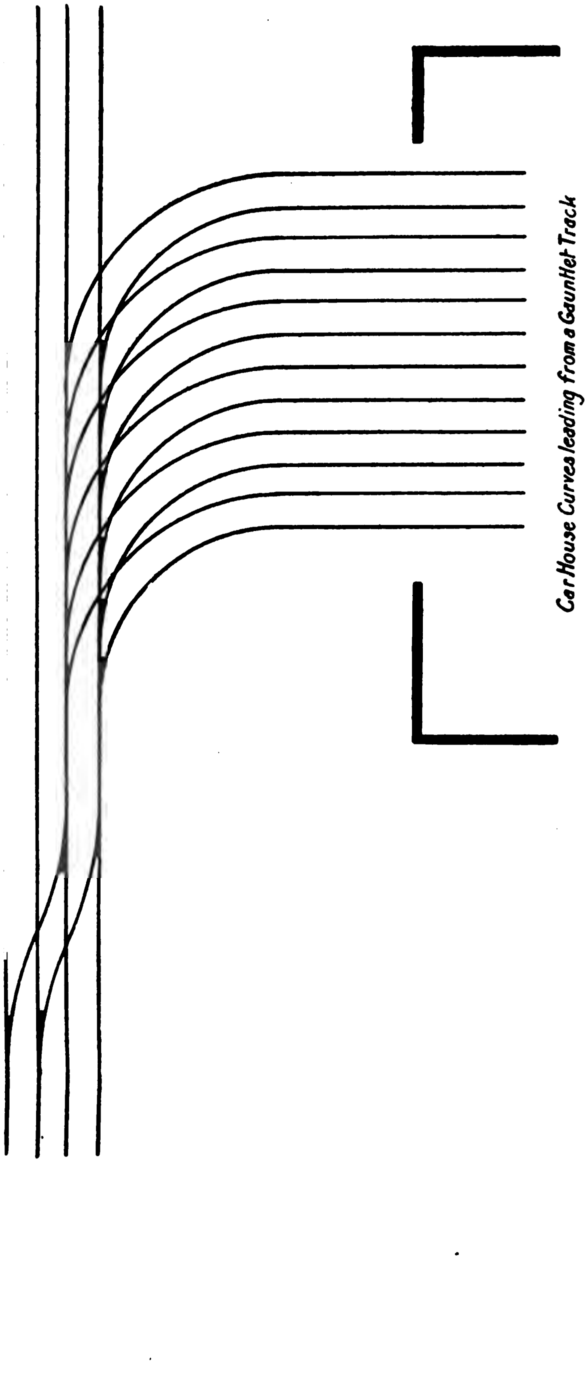
FIG. 19.—DOUBLE-TRACK RIGHT-HAND BRANCH-OFF.

Rails Partially Exposed.

80° Fahr.	No space.
50° to 80° Fahr.	$\frac{1}{16}$ inch.
30° to 50° ,, ...	$\frac{1}{8}$ inch.
Below 30° ,, ...	$\frac{3}{16}$ to $\frac{1}{4}$ inch.

Rails Wholly Exposed.

80° Fahr.	$\frac{1}{16}$ inch.
60° to 80° Fahr.	$\frac{1}{8}$ inch.
40° to 60° ,, ...	$\frac{3}{16}$ to $\frac{1}{4}$ inch.
30° to 40° ,, ...	$\frac{1}{4}$ inch.
Below 30° ,, ...	$\frac{5}{16}$ inch.



Car House Curves leading from a Gauntlet Track

FIG. 20.

The tables on page 14 refer to the spaces which must be allowed for between abutting rails at the corresponding temperatures when the rails are laid. The spaces are left so as to allow for expansion and contraction with increase and decrease of temperature, to which the exposed and partially exposed rails are liable to be subjected.

On straight lengths of the track the rails are laid level, but on going around curves the outside rail ought to be elevated above the rail on the inside of the curve. The amount of elevation depends upon the speed in miles per hour at which the cars go round the curve, and also upon the radius of the curve.

Let E = the elevation in inches
V = velocity in feet per second
R = radius in feet.

Then

$$E = 1{\cdot}7546\,\frac{V^2}{R}.$$

It will be seen that the elevation increases directly as the square of the velocity and inversely as the radius.

Elevation in inches = constant ÷ radius of curve in feet.

The constants on page 17 are obtained by reducing the miles per hour into feet per second, squaring this velocity and multiplying by 1·7546; any of the above constants divided by the radius in feet, will give the amount in inches which the outside rail has to be elevated at the speed corresponding to the constant used.

Speed in Miles per Hour.	*Constant.*
3	33·969
4	60·389
5	94·353
6	135·876
7	184·917
8	241·557
9	305·721
10	377·412
12	543·505
15	849·18
18	1222·88
20	1509·65
25	2358·82
30	3396·90
35	4622·92
40	6039·25

In the design and laying out of the permanent way, the great object is to keep the radii of the curves as large as possible and the gradients as low as possible. This fulfils a condition which (if the track is properly constructed) gives safety, and the maintenance cost of the rolling stock and permanent way is kept low. A well laid out and substantially constructed permanent way increases the life of the cars and also of the track itself.

All of the diagrams on the laying out of permanent way in this book are planned on a gauge of 4 ft. 8½ in., with a distance of 4 ft. 4 in. between pairs of rails, where a double track is used.

In the laying out of a double track permanent way

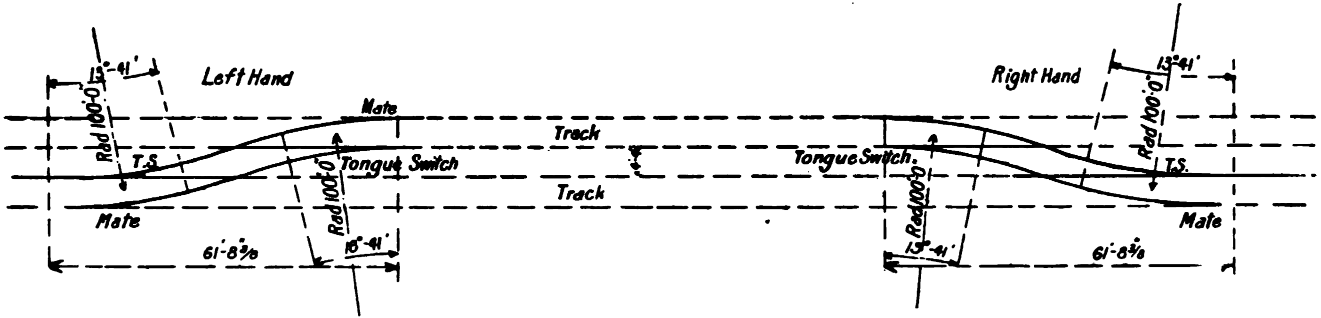


FIG. 21.—STANDARD LONG CROSSOVER 13° 41' FROGS.

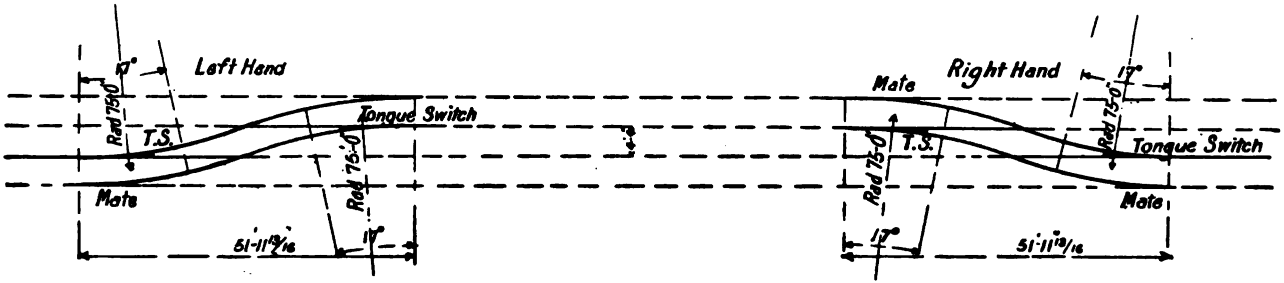


FIG. 22.—STANDARD SHORT CROSSOVER 17° FROGS.

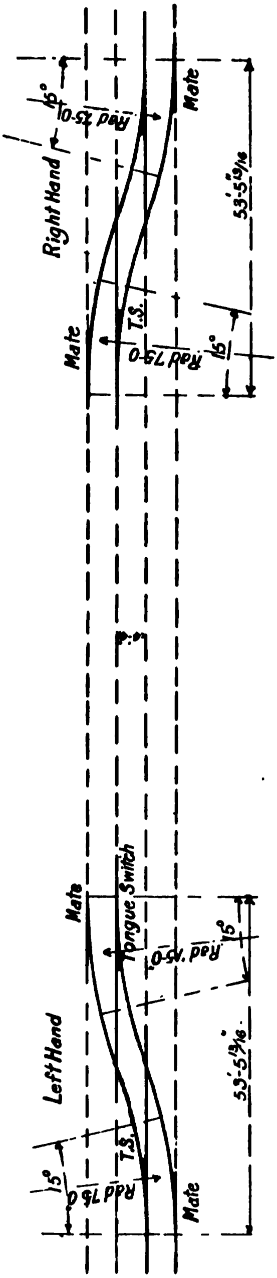


Fig. 23.—Standard 15° Crossover 15° Frogs.

system, it becomes essential to construct crossovers at intervals of the route. This is advisable so that cars can cross over from one track to another in case of necessity.

Fig. 21 illustrates a Standard Long Crossover with 13° 41′ frogs.

Fig. 22 illustrates a Standard Short Crossover, with 17° frogs.

Fig. 23 illustrates a Standard 15° Crossover, with 15° frogs.

All of the necessary dimensions are given in the above figures. It is not advisable for practical reasons to construct the "Turnout Curves" of a less radius than 100 feet, or "Standard Crossovers" of a less radius than 75 feet. The importance of keeping the radii of curves large, may be gathered from the fact that when a car is going round a curve of 50 feet radius, the resistance to traction is doubled and even trebled, if there be sand on the rails.

On tramways in towns it is not convenient generally to raise the outer rail in a curve to a higher level than the inner one. There is no safeguard against effects of the force tending to keep the moving mass in a straight line. It is, therefore, all the more desirable to provide flexible wheel bases, in order to prevent the wheel flanges from riding over the inner edge of the rail, and thus leaving the track.

CHAPTER II.

ROAD BED FOUNDATION, ETC.

Before the rails are laid, the road or track bed has to be prepared; it is highly important that a good substantial foundation road bed be prepared ; we can never expect to have a good reliable permanent way, unless the road bed construction and foundation are of the best. A cheap road bed is the most expensive in the end, because before many years have gone by, the extra cost of maintenance of the permanent way (due to a defective and weak foundation) will very soon eat up the extra money saved initially in preparing a cheap road bed ; a flimsy foundation will never be satisfactory, will always be under repair, and will absorb too large a percentage of the road earnings to keep it maintained in anything like a satisfactory and safe condition ; too great stress cannot be laid upon this important and vital point.

It may be taken as an established truism that, no matter how well the rails themselves are laid, how accurately they are gauged, or how substantial they are made at the joints by sole-plates and anchoring beams, they will in time (on a poor foundation) get out of gauge, and slightly tilt, joints will vibrate loose and will become undulated, i.e. the rails will not

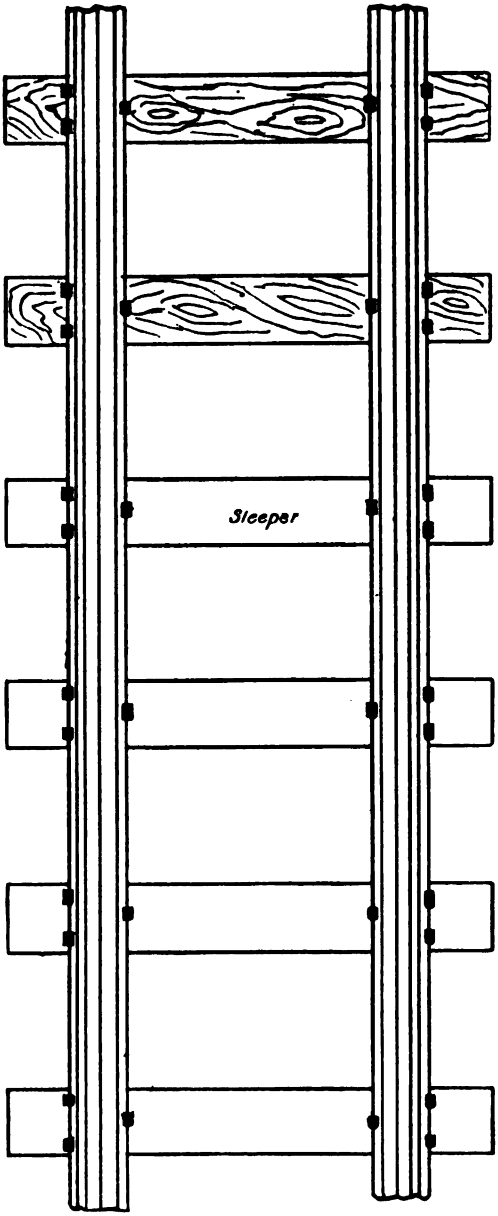


FIG. 24.

remain flat owing to the sinking and lateral bulging of the foundation.

In the United States it has been a generally adopted method of permanent way construction, to lay the rails or metals on wooden sleepers or ties (see Figs. 24 and 25). The rails are spiked to the wooden ties or sleepers on each side of the rail flange; the sleepers are made of oak, redwood, cypress, cedar and some soft woods.

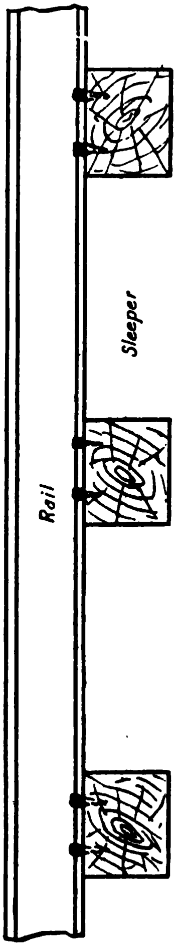


Fig. 25

The inherent weakness of the sleepers or ties is the fact that in streets they become more or less soft with moisture, also the rails cut into the ties (unless otherwise prevented); the spikes become loose and the rails cant, the true gauge is not preserved, and the rails undulate; rails have been known to cut into the wooden ties from 1½ to 2 inches. Wooden sleeper or tie-construction has a tendency to cause buckling or curling up of the flanges of the rail, also a rolling or canting and spreading of the rails, especially on curves.

To prevent rails from cutting into the ties, a tie plate is generally used (see Figs. 26 and 27). A tie plate is a flat plate of steel with flanges on one side; it is attached on the upper side of the wooden sleepers or ties in order that the rail may rest thereon. The advantages of using tie plates on the sleepers or ties are that they prevent the cutting in of the rail into the sleeper, and their perfect under-support holds the rails in a perpendicular position and prevents any rolling or canting of the rails; undulations (due to cutting in) are also prevented and the true gauge is preserved. After the rails are spiked to gauge on the ties, the road is finished off flush with the tread of the rails.

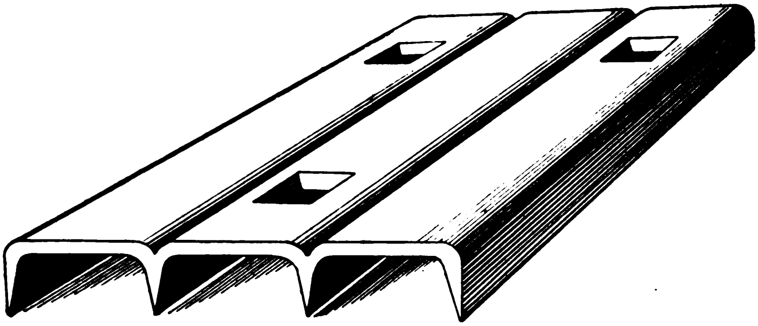


FIG. 26.

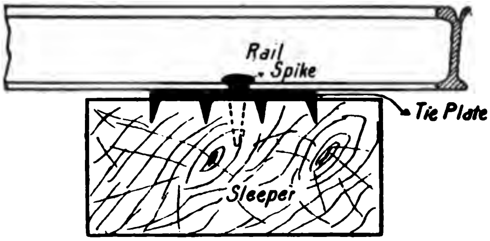


FIG. 27.

In England the rail bed or foundation is generally of concrete. The first preparation consists in opening up the road to the desired depth; if this is a macadam roadway it is done by a gang of men, one section of which opens up the hard top surface by means of large drift spikes driven in by sledge hammers, another section using the pickaxe; the substance is removed to the side of the road or out of the way in wheelbarrows by a third section of the gang; while a fourth section is preparing the troughs or trenches, and still another section is mixing up the concrete.

The troughs or trenches (this method of rail foundation or bed is the general way of town and city construction) are opened up to a depth of from 6 to 12 inches, and about 18 inches wide. The depth and width, however, depend a great deal upon the nature of the ground (see Fig. 28). The trenches are then filled up with concrete to the required depth, which is patted down and smoothed over. A good concrete is composed of 5 parts broken stone, 2 parts sand and 1 part Portland cement.

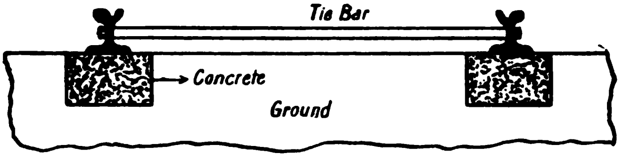


FIG. 28.

The concrete should be allowed to become well set before the rails are placed in position, but in large towns, where the roadway has to be opened and closed as quickly as possible, the rails are fixed as soon as the concrete is smoothed and ready—in fact the operation of digging the trenches, filling with concrete and placing the rails in position, follow each other as rapidly as possible.

It will be noticed that in the above method of preparing the foundation the road bed is only concreted in a strip about 18 inches wide under each rail. This method of foundation preparation becomes imperative in large and busy cities, because it is a speedy and quick method, besides being also a comparatively cheap one.

The above method, however, is rather a cheap makeshift method of preparing the track foundation.

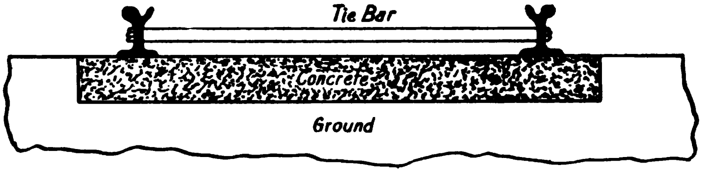


Fig. 29.

The substantial and satisfactory method of thoroughly preparing a track bed, is to concrete it all the way across (see Fig. 29) to a depth of from 6 to 12 inches and about 6 feet wide, that is, to make a solid concrete road bed for the track of the above dimensions; so comparing this method with the previous one, instead of having 2 trenches about 6 to 12 inches deep by 18 inches wide (one under each rail), we have one large trench under the track about 12 inches deep and 6 feet wide, filled with concrete.

This is the only proper method of foundation construction, and has been adopted by a number of good corporations. Of course it is a more costly method, since more ground has to be opened out, it takes a longer time, and more cubic feet of concrete have to be used for equal lengths of tramways; but although it is more costly at first it is much the cheaper in the end, because, when once the pavement has been set over a solid concrete foundation its permanent level position is assured, whereas in the previous case the foundation between the rails is not as solid as the concrete foundation under the rails, and the result is, that with time the foundation sinks and undulates, and the pavement above it also sinks, owing to the effects of rain and heavy traffic over the streets; the result of this is that the pavement has from time to time to be reset. This involves a continual expenditure of money, which as years roll by totals up to a large amount.

In foundation construction it must always be remembered that a sound and solid foundation generally means a very small annual maintenance cost, whereas a cheap makeshift foundation will entail a heavy annual maintenance expenditure, with the additional disadvantage that it is never a permanent and satisfactory job; the secret of good permanent way construction and satisfactory safe and smooth running is, first and foremost, the best foundation possible: there will be very little trouble with the rails and road if this foresighted method is adopted; the rails remain flat, they do not become undulated, they keep true to gauge and give very little trouble indeed—in fact, in nearly every case the everlasting trouble with the permanent way and paving is due to one chief cause, and that is a defective foundation bed.

There cannot be too strongly impressed upon constructional and designing engineers and others, the importance of the best foundation possible: a cheap flimsy foundation is fatal to the best interests of all concerned. In fact, with wood block pavement this is the only foundation construction admissible. Wherever possible the concrete foundation should be allowed to become well set before the track is laid. This is a very important consideration, which is very often overlooked.

When the rails are laid upon wooden sleepers or ties, the ties should be wholly embedded in concrete; the wooden tie construction, however, is not used in this country in town and city construction (see Fig. 30).

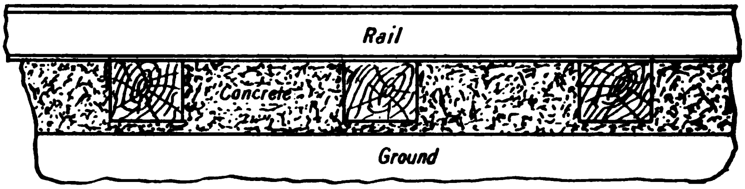


Fig. 30.

In concluding this chapter on foundation construction I take the liberty of quoting the remarks of a well-known authority on road construction, who says: The importance of a properly constructed and rigid foundation for all weight-carrying streets cannot be overstated. It is the foundation which carries the weight; the material with which the street is paved is merely the skin or veneer to preserve the "real" roadway, i.e. the foundation underneath.

CHAPTER III.

LAYING THE RAILS, PLATE LAYING, BONDING, ETC.

THE next step in order after preparing the road bed and track foundation is to lay the rails or track. The rails are supplied in lengths of from 30 feet to 60 feet long, and vary in weight from about 85 lb. to 110 lb. per yard. The weight adopted depends upon local conditions as regards heaviness of street traffic.

When the rails are delivered along the roadway, a man is generally set to work to drill the holes required for the rail bonds, the position of the holes being marked out for the driller; the fish-plate holes are generally already in the rails when delivered, but the bond holes as a rule have to be drilled after delivery; when all is ready for the laying of the rails in their final position they have to be moved or carried by some convenient means; the best and simplest method is to utilise the "portable rail carriage," as shown in Fig. 31.

This consists of 2 two-wheeled carriers, with a strong hook, chain and claw grips or clamps, which form part of a strong frame supported on the axle of the wheels; by raising the handle of the carriage the hook and chain drop down low enough for the claws or grips to be applied to the rail tread or flanges, and on lowering the handle the carrying framework rotates about the axle of the carriage as a fulcrum, and raises the rail about 9 inches off the ground; the rail can then readily and quickly be moved from place to place; to drop the rail it only requires the handle to be raised, when the rail is lowered and the chain and grip are taken off. The rail is then rolled over into position on the concrete foundation by means of the application of crowbars, and is jointed to the next rail by means of fish-plates, and in the majority of cases by the addition of sole-plates (placed under the flanges of the rail), and sometimes anchor sole-plates of I beams or girder rails.

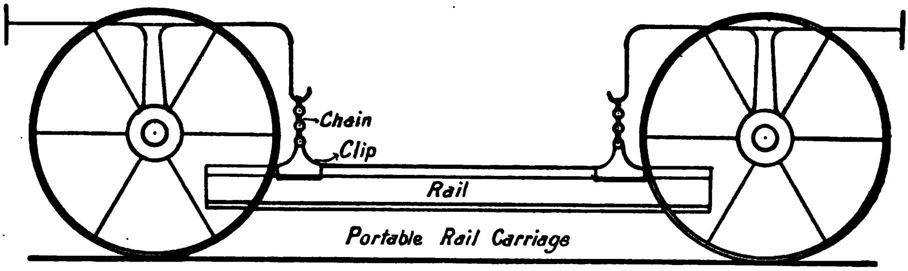


FIG. 31.

This combination of fishplating and anchor sole-plates is for the purpose of overcoming the difficulty of the joints becoming loose with continual vibration due to the traffic over them (see Figs. 32 and 33). These two methods were adopted, one at Brighton (Fig. 32), and one at Lancaster (Fig. 33); and are examples of about the best way of securely jointing the rails; these methods of construction are to be highly commended.

The method adopted at Brighton was to connect the rails together by bolting strong fish-plates (Fig. 36), weighing about 46 lb. per pair, with 20-inch steel sole-plates under the rail joint, resting on and bolted to a 6-inch steel girder sleeper running transversely to the rails. The method adopted for laying the permanent way will be described in another chapter later on.

At Lancaster (Figs. 33 and 34) the rail joints are supported by anchor sole-plates, of 60 lb. weight and 24 inches long, inverted and riveted to the bottom of the running rail.

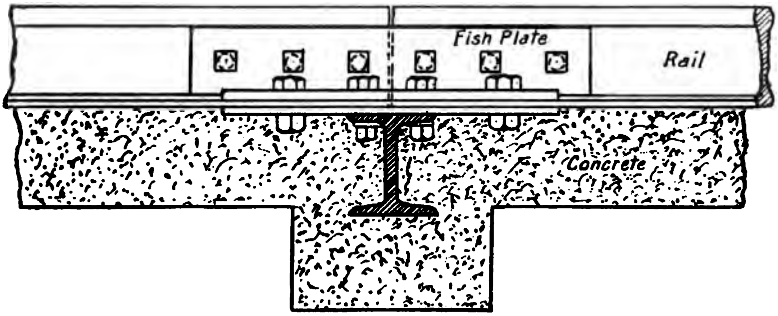


FIG. 32.

After the rails are bolted together they are set true to gauge and kept to gauge by means of tie-bars (see Fig. 35), placed in position about every 10 feet apart (closer together around curves); the tie-bars as seen from the figure are held securely in position by being screwed up tight by nuts on each side of the rail web. The cross-ties or tie-bars are of steel, and about 2 inches deep and $\frac{3}{8}$ inch wide.

After the rails are tied they are set level and flat by means of the level board and spirit level from rail to rail; to see if the rail is flat lengthwise it is generally sighted, by looking along the tread of the rail with the eye level with the surface. If there are any sags or undulations in the rail it is raised by crow-bars and packed and rammed under with concrete. If there are any kinks in the rails (which throw the gauge out of truth), they are straightened by means of the hydraulic or screw-jack (called a "jim crow"). While the rails are being joined by the fish-plates they are bonded, generally by means of "copper rail bonds." It is very important that the rails should be thoroughly and solidly bonded.

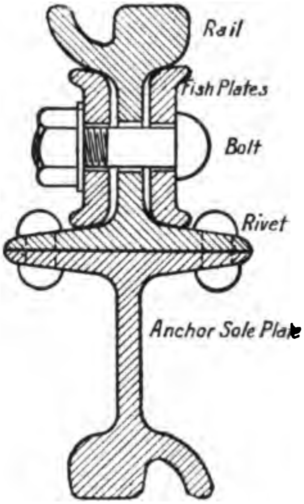
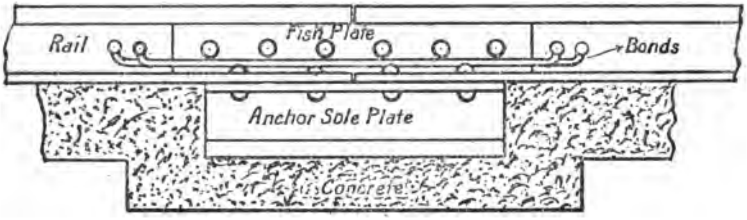


Fig. 33.

The great importance of efficient "rail bonding" is very often under-estimated; in fact it is one of the most important operations in permanent way construction. The object of bonding the rails is the following. The return electric current, after passing from the trolley wire and through the controller and motors, is conducted back to the power house by means of the rails themselves, or, in other words, the rails form the return circuit for the electric current; this necessitates that the rails should be continuous electrically. Now at each joint in the rails the electrical continuity is broken, and it becomes necessary to bridge over the joint by a conducting path of very low resistance (we must keep the resistance to the lowest possible limit, otherwise we get an excessive fall of voltage and leakage of current to earth, which maximum amount is fixed by Board of Trade regulations); this object is attained by a thorough and secure method of bonding.



Elevation of Rail Joint

FIG. 34.

Before the lug of the bond is inserted into the drilled hole, the hole itself should be freed from all grease, rust and dirt, by being cleaned with a rag or waste and emery cloth, so as to present a perfectly clean metallic surface. The reason for this is that dirt and oil prevent a good metallic contact and increase the electrical resistance of the surface of contact between the copper lug and the web of the rail. After the hole is thus prepared, the lug of the bond is inserted and is securely expanded against the metal of the web generally by means of a drift or tapered expansion stud or pin driven tightly in. A flexible rail bond invented by the writer of this book is shown in Fig. 37.

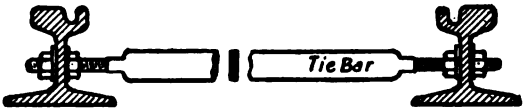


FIG. 35.

The advantages claimed for flexible rail bonds over the solid type of rail bond, are that they are not so likely to vibrate loose; and they more readily conform and bend around and lay nearer to the fish-plates and web of the rail. There are several good types of rail bond, viz. the Columbia, Chicago, Neptune, and Bowker rail bonds.

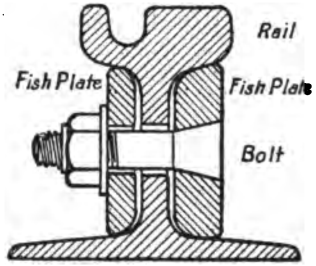
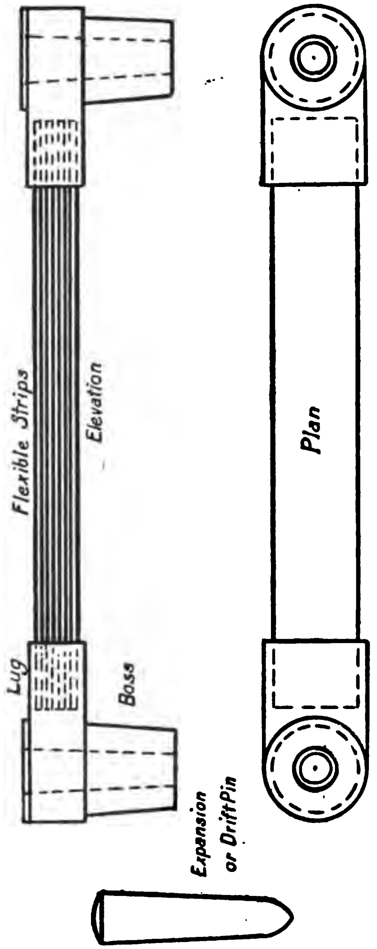


FIG. 36.

In rail bonding there is generally a short flexible or plastic rail bond placed across the joint, and connecting the rails before the fish-plates are placed in position and bolted up, and after the fishplating is done there are fixed two copper bonds across each rail joint on the outside of the fish-plates; this is called "double bonding" the rail joint. In addition to being double bonded across each rail joint they are "cross bonded" about



Flexible Rail Bond

FIG. 37.

every 40 to 80 yards, but should be "cross bonded" across each pair of the rails, in the middle of the length by a single bond. In the case of a double track they are sometimes, and should be in all cases, cross bonded from one pair of rails to the other pair of rails, at a distance apart of about every 50 yards.

The copper rail bonds are made of hard drawn copper, and have a carrying capacity (current) equal to from 00 to 0000 S.W.G. After the rails are bonded, the copper bonds are painted all over as a protective coating. There are other methods of bonding rails in addition to copper bonding, viz. (2) plastic bonds connecting the web of each rail to the fish-plate by means of a metallic amalgam; (3) electrically welding the rails at the joints; and (4) cast welding the rails at the joints.

The objects attained by providing a good return, which to a great extent, depends upon good and efficient bonding, may be stated to be:—(1) economy in line losses and efficiency of the circuit; (2) preventing undue interference with telephone and telegraph lines due to leakage; (3) prevention of electrolysis of metal pipes laid in the ground for the conveyance of gas and water.

After the rails are well bonded and levelled by packing and ramming under fine concrete, there is run under and around the rail flange a skimming or veneering of liquid cement; after which there is plastered on each side of the rail web the full length of the rails, and also around the tie-bar, a thick mixture or paste (rail filling), generally composed of sand and cement or fine concrete.

CHAPTER IV.

COMPLETING THE ROADWAY.

IN the construction of electric light railways through country, the rails or track are generally laid upon wooden sleepers, and either spiked to the sleepers or supported true to gauge in cast-iron chairs, similar to English railroad permanent way construction. The chair-support construction is the best and most solid method.

In light railway construction the road bed is not finished off the same as paved streets; but to give the track sufficient rigidity and keep it safe the space between the sleepers is, or should be, levelled up with ballast; or better still, the track should be ballasted up to the tread (see Fig. 38). Ballast is broken stone or slag.

The wooden sleepers used in this country consist of heavily creosoted wood; they possess greater durability than the untreated timbers used in America. Light railways in the future will play a great part in the development of rural districts, in the connecting of towns, and in the carriage of goods.

In the completion of the tramways we will confine our attention to city and town street construction. Modern experience has shown that the best foundation for all paved roadways is undoubtedly that composed of cement concrete; this is the foundation already described.

In the selection of paving material, the gradient of a street to some extent decides the question of the material to be employed for paving. Mr. H. Percy Boulnois, in his excellent book on 'Carriageways, etc.' says: "Asphalt would necessarily be unsuitable for streets of steeper gradient than 1 in 60; wood, 1 in 36; and stone setts, 1 in 16. Again, it is evident that a pavement which would be eminently suitable for a heavy commercial traffic would be quite out of place for that of a health resort, or of a quiet provincial town."

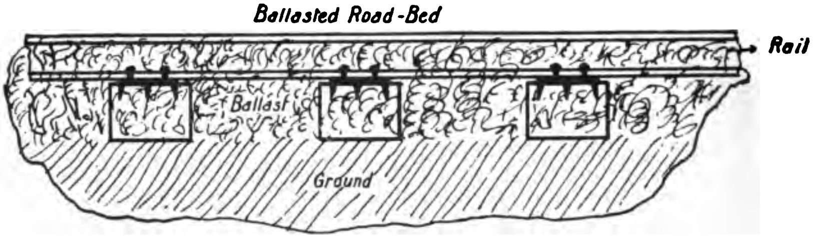


Fig. 38.

The width of a street also has some bearing on the subject of the selection of a paving material,—as wood, for instance, is not advisable in a narrow street, where, owing to the height of the buildings on either side, the light and air are excluded. In large commercial cities like Manchester and Liverpool, the paving used would generally be granite or syenite setts.

As regards wear, there is no pavement that has yet been discovered with so long a life as granite sett pavement, properly laid with judiciously selected granite or syenite. The advantages of such a pavement may be summarised as follows:—(1) Adaptability to most gradients; (2) suitability for all classes of traffic; (3) durability; (4) fair foot-hold; (5) ease of traction; (6) minimum of dust and mud; (7) facility of cleaning; (8) less trouble in repairing.

The size and shape of the setts depend upon certain conditions; for stability a certain proportion must exist between the depth, length, and breadth, and 7 inches has been fixed as a sufficient and proper depth for any class of traffic. The width is somewhat controlled by the size of the horses' hoofs (so as to get a good foot-hold) and about 4 inches is now allowed to be the maximum width. The length of the sett is governed principally by the ease of handling by the pavior, and so laid that each sett must break joint properly with its neighbour, and must not be too long, as it is apt to ride and tilt. Nine inches may be considered as quite long enough.

The following sizes of stones may be taken as satisfactory:—

Setts . .	6¼ in. × 3¼ in. × 5 in. to 7 in. long.
,, . .	7¼ in. × 3¼ in. × 5 in. to 7 in. long.
Cubes . .	3¾ in. × 3¾ in. × 3¾ in.
,, . .	4 in. × 4 in. × 4 in.
Blocks . .	4 in. × 4 in. × 6 in. deep.
,, . .	3¼ in. × 3¼ in. × 6¼ in. deep.

It is of the greatest importance that the setts should be thoroughly square and not taper, and that the dressing should be most carefully carried out, and there ought not to be a difference of more than ½ inch between the broad and thin ends of the setts. It is highly important that all setts should be gauged and dressed uniformly, and that they should be laid as closely together as possible, because the slight inequalities provide sufficient joint for the grouting, and the nearer the setts are laid together the less the noise of the traffic, and the less the liability of the arrises (edges) to wear.

It is also important to lay the setts on a cushion bed of sand about ½ inch in thickness, as this transfers the pressure to the foundation equally, and gives some elasticity to the bed; this prevents the stones being crushed, which might otherwise take place if they were laid directly on the rigid concrete foundation. The cushion bed must be of fine sand, as otherwise there might be a liability of the setts to ride. This bed is also of great value where the setts are grouted with a bituminous mixture, and not with cement; the former is generally admitted as being preferable.

The following is a specification of paving for first-class streets:—The paving shall consist of granite or syenite setts 3¼ inches wide by 6¼ inches deep laid in regular, straight, and properly bonded courses with close joints, and be evenly bedded on a layer of fine gravel ½ inch in thickness after the paving is laid; the joints shall be filled with hard, clean, dry shingle; the setts shall then be thoroughly rammed and additional shingle added until the joints are perfectly full. The joints shall then be carefully grouted until completely filled with a hot composition consisting of coal pitch and creosote oil; and, finally, the paving is to be covered with ½ inch of sharp gravel.

For second-class streets the paving shall consist of granite or syenite setts 3 inches wide by 5 inches deep, or of granite or syenite 4 inch by 4 inch cubes laid, bedded, jointed, grouted, etc. as above. Wood as a paving material is greatly used in London and some other towns, especially seaside resorts; several varieties of wood are used, such as pine of all sorts, oak, ash, beech, elm, red gum and the Australian Jarrah and Karri woods. Whatever wood is selected, it should be thoroughly sound, and free from all traces of sap, close-grained, and uniform in quality, free from knots or shakes, and every block should be examined before being used. It is not necessary to have "seasoned wood," as it appears from experience that the wood is better for having a little "life" in it.

It is claimed for the Australian woods that, though considerably dearer than Baltic or American deals, their life is longer under the traffic, and that they require no creosoting, and being close-grained, they are more sanitary. With reference to the question of creosoting the softer woods, this does not add to the life of the block, but renders it less absorbent, and consequently more sanitary. At least 10 lb. of creosote oil should be driven into every cubic foot of wood, under such a pressure as will ensure this, and a few blocks should be cut in half from time to time to see if the creosote has thoroughly penetrated. Whatever wood is selected, and whether treated or not, the blocks should be cut die square with the fibre vertical, a convenient and much used size being 9 inches by 6 inches by 3 inches on the face. The blocks must be laid with the fibre of the wood quite vertical, because in this position the wear is least.

The foundation of a wood-paved street must be of concrete. In some cases a cushion bed of sand or fine gravel is laid upon the concrete about ½ inch in thickness; in London practice and elsewhere the blocks are laid directly upon the surface of the finished concrete. In the former case, it is found that the grouting, if of bitumen, sinks into the cushion bed, and prevents the upheaval of the blocks, which sometimes occurs where this cushion bed is not provided.

There is also a difference of opinion on the question of joints between the blocks. In some cases they are laid with an open joint between them, about ¼ inch or ⅛ inch wide, and this joint is filled up with "racking," composed of dry, clean, sharp, or rounded gravel or pebbles about the size of beans or small nuts, which is afterwards filled in with a bituminous mixture, consisting of three of pitch to one of creosote oil, well boiled together.

It is found that wood is absorbent of moisture, with a consequent swelling, and it is contended that "racking" when employed enters into the sides of the blocks, and thus takes up the extra space required for this swelling or expansion, and prevents upheaval or the forcing away of the kerbs at the sides of the roadways. The expansion due to this swelling of the wood, owing to the absorption of moisture, varies with different woods; it is very small with the Australian hardwoods, but considerable with the softer pine woods (unless chemically treated), amounting in some cases to as much as 1¼ inches in 8 feet.

In order to prevent upheaval, or movement of the blocks, an expansion joint filled with clay is sometimes left about 1½ inches wide parallel and close to the kerb on each side of the roadway; in other cases, "dog-toothing" is resorted to, so that each transverse row of blocks has an expansion joint of about 4½ inches. Figs. 39 and 40 explain these systems.

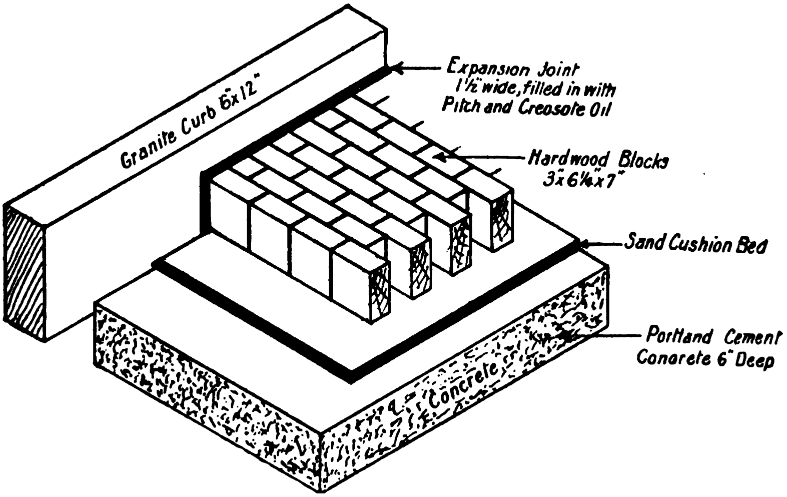

Granite Curb 6"x12"
Expansion Joint 1½" wide, filled in with Pitch and Creosote Oil
Hardwood Blocks 3"x6¼"x7"
Sand Cushion Bed
Portland Cement Concrete 6" Deep
Concrete

FIG. 39.

Pitch grouting is preferable to cement grouting for the following reasons. Pitch grouting allows the joints to be reduced to $\frac{1}{16}$ inch wide; thus soft wood blocks may be in close contact and so prevent the fibre spreading, and this preserves the life of the wood—it is more elastic than cement, and consequently absorbs expansion and gives way to contraction. It is also impervious, and the pitch joint next the wood helps to preserve it. Traffic may be turned on directly the joint is cool, and it is easier applied than cement grouting. The disadvantages of an open transverse joint between the blocks in wood pavement are that they expose the arrises of the blocks to attrition and rounding off by the traffic, thus making a bumpy and noisy road, and also that mud sticks in the joints and is difficult to dislodge, thus adding to the slipperiness of this description of pavement.

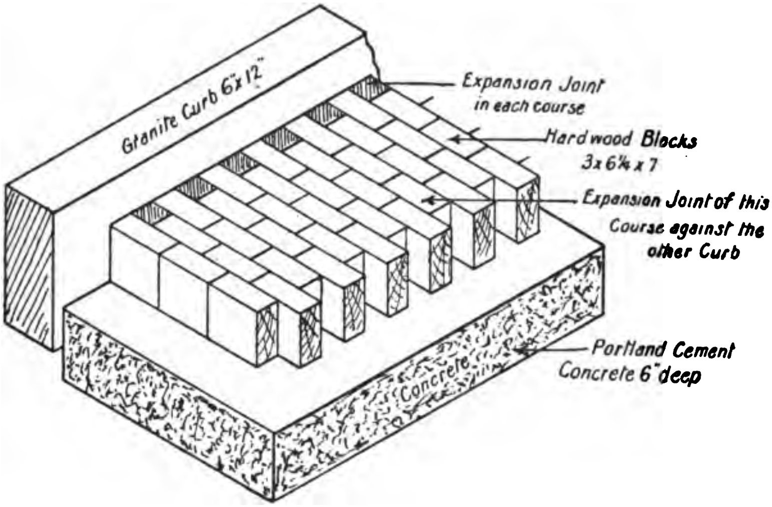

Granite Curb 6"x 12"
Expansion Joint in each course
Hardwood Blocks 3x 6¼ x 7
Expansion Joint of this Course against the other Curb
Portland Cement Concrete 6" deep
Concrete

Fig. 40.

The more modern practice, consequently, is to do away with all joints between the courses, and the blocks are laid close together, the sides and ends touching, hot tar being laid over the surface and brushed or "squeegeed," until it disappears between the blocks, expansion being provided for in the manner already described.

In all cases of wood pavement it is necessary to cover the finished surface with a half-inch coating of clean, sharp shingle, gravel, or pebbles, about the size of beans or small nuts, leaving the traffic to squeeze it into the top surface of the wood, which preserves its life and renders it less slippery. Wood is unquestionably an excellent pavement for streets of light traffic, but it would not stand the crushing weights of a heavy mercantile traffic such as that in some of the streets in Manchester and Liverpool. Nor can it be used on streets where the gradient is steeper than 1 in 27; for though its slipperiness may be much minimised by sanding or gravelling, there are times when the peculiar atmospheric conditions of our climate render it very slippery.

Wood pavement has one most serious disadvantage—it offends more than any other against public hygiene.

Fig. 41 represents the track laid in position, also a section of the street paved and finished off with either wood blocks, or granite, or syenite setts. In wood paving, it is generally finished off "proud" with the tread of the rail. In paving with hard granite or syenite setts, the abutting setts are generally laid "proud" of the rails, but where the setts are of exceptionally hard quality, they ought to be laid or finished off about $\frac{1}{8}$ inch below the tread of the rails, because the metal of the rails wears away more quickly than the granite or syenite setts.

The method of laying the wood pavement on the electric tramway track in Lord Street, Southport, was the following. A concrete foundation was prepared; the Australian wood blocks were then dipped to the depth of about 2 inches in a bituminous mixture, then laid in position, after which they were grouted to within about 1 inch of the top with bitumen, which was finished by having a liquid cement brushed or "squeegeed" over the blocks, until it disappeared and filled up the remaining inch.

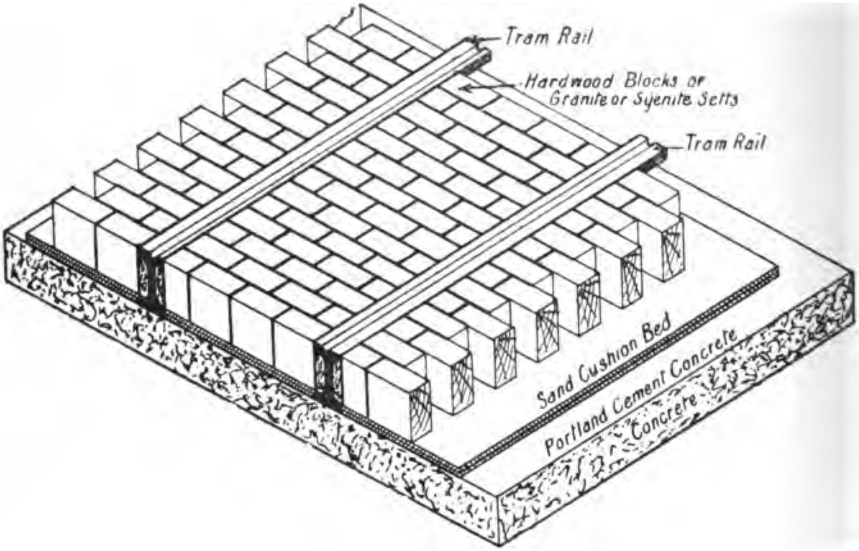


FIG. 41.

When finishing off a pavement by grouting with bitumen, the bituminous mixture should not be allowed to run into or fill up the grooves of the rail, otherwise it is very hard to get rid of. This is prevented by pouring water in the grooves of the rails and filling the grooves with gravel and dirt; when the track requires to be used this is easily removed with a groove iron (a piece of iron about 4 feet long, 1 inch in diameter, and pointed at the end) which is pushed along the groove of the rail, thereby loosening the dirt and gravel, which can then be brushed away, leaving the track clean, smooth and free from any sticky, tarry products.

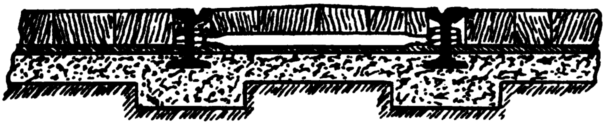


FIG. 42.

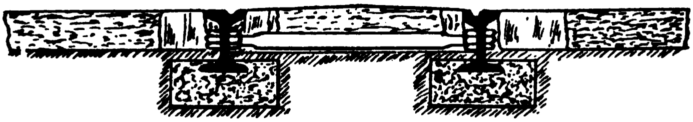


FIG. 43.

Figs. 42 and 43 represent cross-sections of the track and roadway as constructed on the trolley routes at Bournemouth, the streets being finished off with "wood pavement" and macadam respectively, as illustrated. In granite or syenite sett paving, it is not necessary to have any expansion joints, all the setts being jointed or laid close up. The ordinary tools used in street paving are too well known to need any detailed description thereof. Such tools are the concrete smoother, pavior's hammer, rammer, sett-dresser's and sett-cleaner's hammer, cement mixing boards, pitch-boiler, pitch-carrier, pitch-bucket, pitch-scoop, etc.

CHAPTER V.

CHOICE OF MATERIALS FOR THE OVERHEAD EQUIPMENT. THE LAYING OUT OF CURVES.

PASSING on from the completion of the permanent way, etc., to the necessary equipment for carrying and supplying the electrical energy to be utilised by the motors of the electric cars, the general outline of the electrical circuit is simply illustrated in Fig. 44.

In the overhead equipment or construction of an electric tramway system, the same remarks and advice are applicable as were given in regard to the permanent way construction, etc. All the materials, appliances and apparatus used in the overhead equipment should be of the very best, constructed on a scientific and thoroughly practical basis, and laid permanently and solidly in position.

The choice of satisfactory materials is very important, and it is advisable always to take a thoughtful and preliminary survey as regards the conditions (local, special and otherwise) which demand certain important considerations in the proposed construction and equipment.

The trolley line may be supported so as to be in position over the centre of the track or at the side of

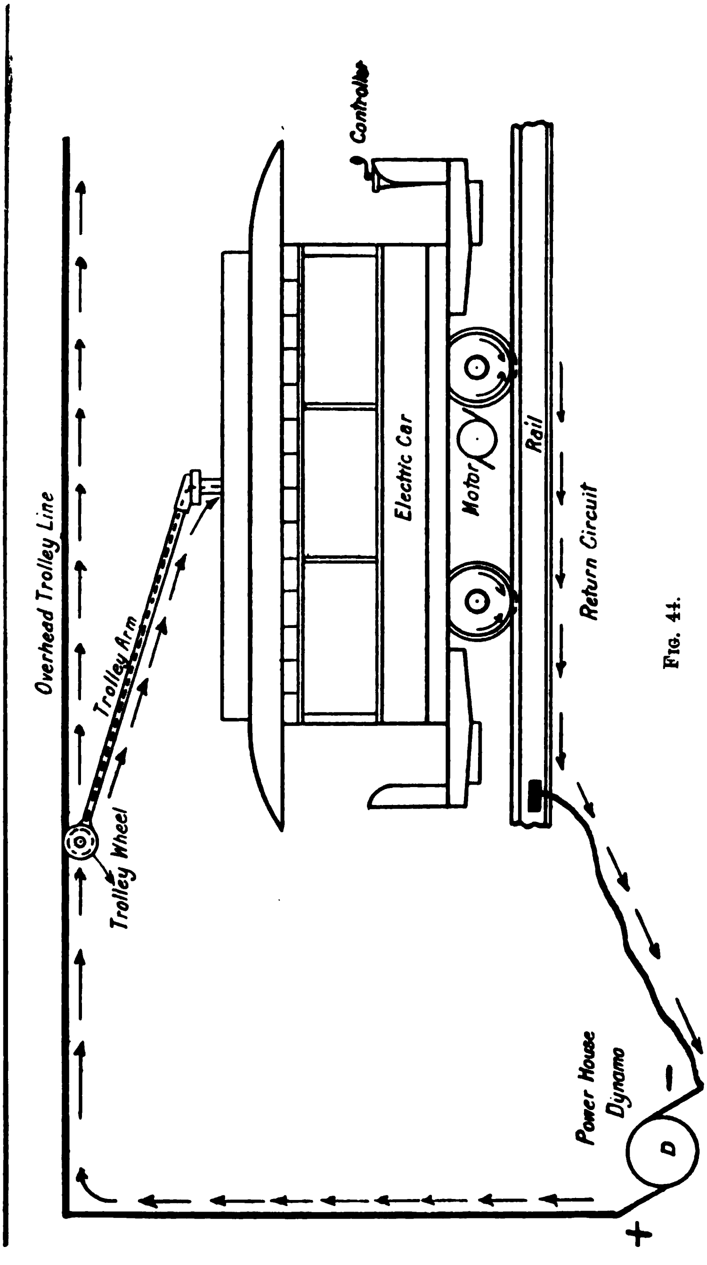

Guard Wire
Overhead Trolley Line
Trolley Arm
Trolley Wheel
Electric Car
Controller
Motor
Rail
Return Circuit
Power House Dynamo
D
+
−

FIG. 44.

the track. Whichever method is adopted depends upon local conditions; wherever possible it is advisable to have the trolley line placed over the middle of the track, one of several reasons being that the trolley wheel and arm are not so liable to jump the trolley wire, another being that there is not so much strain on the trolley wire due to the trolley wheel and arm.

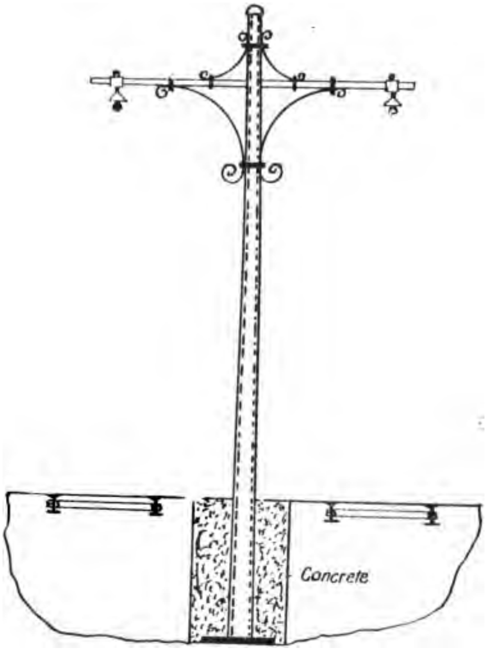


Fig. 45.

On centre line construction the force of pressure of the trolley arm and wheel is directly upwards or vertical, which, while the car is travelling, temporarily takes some of the downward weight and strain of the trolley wire off the hangers and supports, while with side line construction there is a lateral pressure as well as an upward pressure due to the trolley arm and wheel which tends to increase the strain on the supports and hangers; then again, the wear of the trolley wheel and wire is more even and much less in centre line construction than in side line construction.

The method of construction as regards the pole

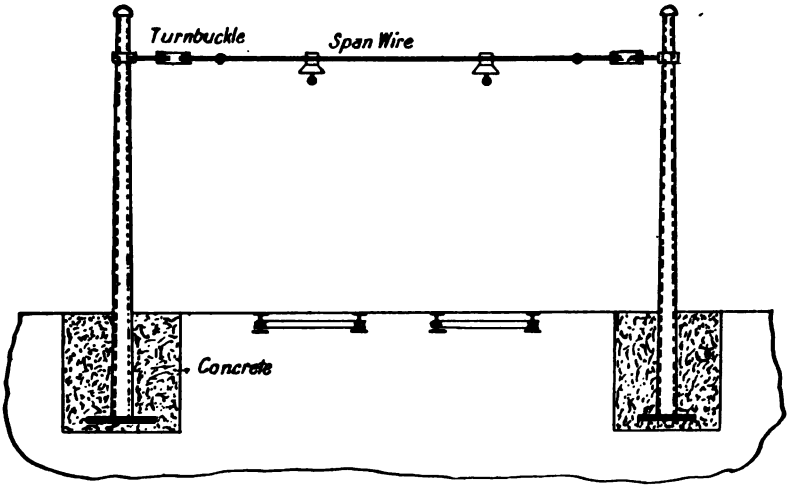


FIG. 46.

supports for the trolley line has to be considered; there is the centre pole construction and the side pole with span wire or bracket arm method; this is determined by conditions such as width of streets (if in a city), whether it is a light railway constructed through country or rural districts, also whether it is a single track or double track; generally speaking, in a good wide street with a double track and plenty of roadway on each side of the track to take the vehicular traffic, centre pole construction is preferable, more economical, has a better appearance, is safer and more compact. This system does away with unsightly and dangerous span wires which are required to support the trolley lines in the span wire construction (see Fig. 45).

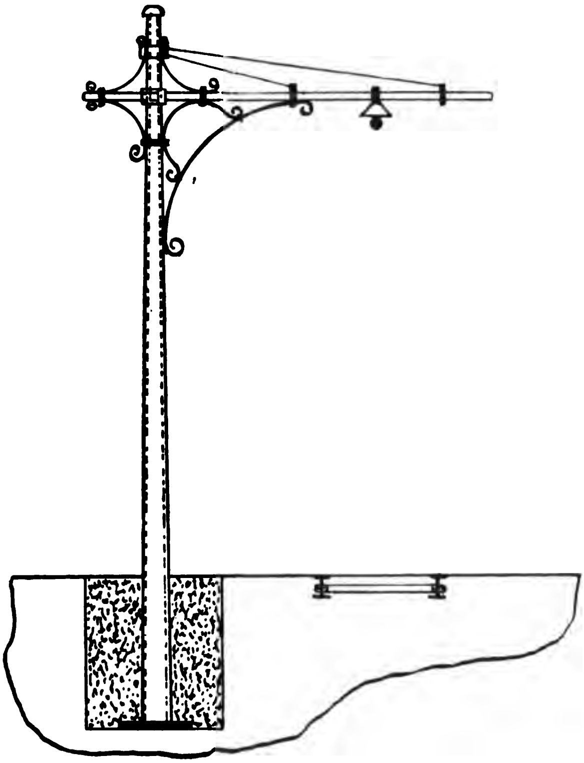


Fig. 47.

The side pole method consists in placing poles on each side of the street (in wide streets), running a strong span wire across the street from pole to pole and supporting the trolley wire thereon (Fig. 46). Another method of side pole construction (which is specially applicable to narrow streets where the roadway is on one side of the track), is to support the trolley line by means of side arm brackets, the poles being placed on one side of the street only (Fig. 47).

In the pole construction of light railways (which are generally constructed of single track with turnouts at intervals) side pole construction is adopted. The choice of the materials used for the pole lies between wood and iron. Wood is generally adopted only for temporary work; although wood poles are greatly used in

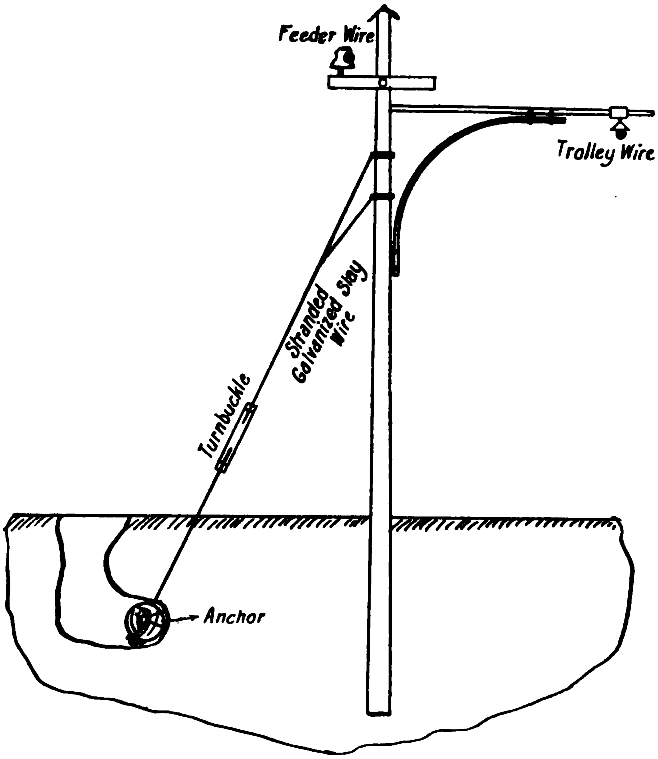


FIG. 48.

the United States, especially in suburban towns and in the country, iron poles are more durable and look better.

Iron pole construction is the best and is the one adopted in England for town and city equipment. In the construction of light railways through country, there is no reason why wood poles should not be greatly used, especially if the conditions are such that wood is cheap and iron costly. Wood poles are more easily stayed and strutted, and under certain conditions of ground and location, such staying and strutting become

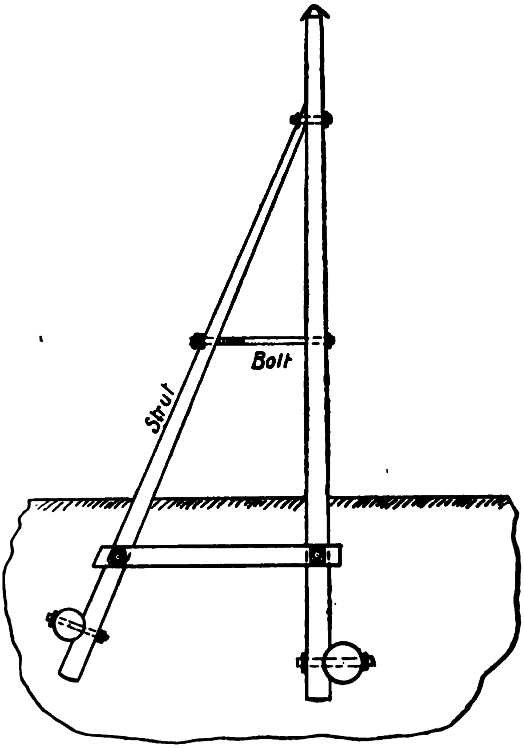


FIG. 49.

absolutely necessary. Good creosoted well planted wood poles are practical for country line construction, and are very convenient for attaching wooden arms with insulators to carry the feeder cables to supply the trolley line with current; in city and town equipment the feeder cables are laid underground in conduits, pipes, ducts, etc. Two good practical methods of staying and strutting a wooden pole are shown in Figs. 48 and 49.

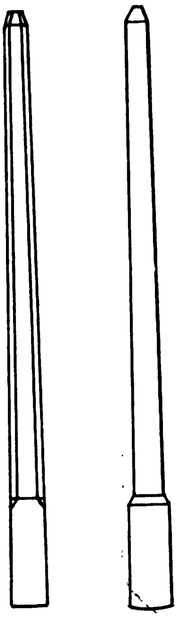


FIG. 50.

In Fig. 50 are shown two standard shapes of wooden pole for tramway work. They are from 26 to 30 feet long, and about 10 to 12 inches at the base, and from 8 to 9 inches at the top. The poles as shown in the figure taper towards the top. The metal poles are usually built up of three steel tubes shrunk together at a welding heat; they vary in length from about 25 to 30 feet. The diameter at the base is generally from 6 to 9 inches, tapering to the top, the diameter of which varies from 4 to 6 inches. In Fig. 51 are illustrated types of steel poles.

Regarding the material of which the overhead trolley wire is composed, the choice lies between hard drawn copper and silicon bronze wire; experience proves that hard drawn copper is the best and most practical. The size used varies from 0 to 0000 S.W.G. depending very much upon choice, although due consideration of local conditions as regards length of line, heaviness of traffic, windage, etc. should be taken into account when choosing it. The sizes mostly used seem to be from

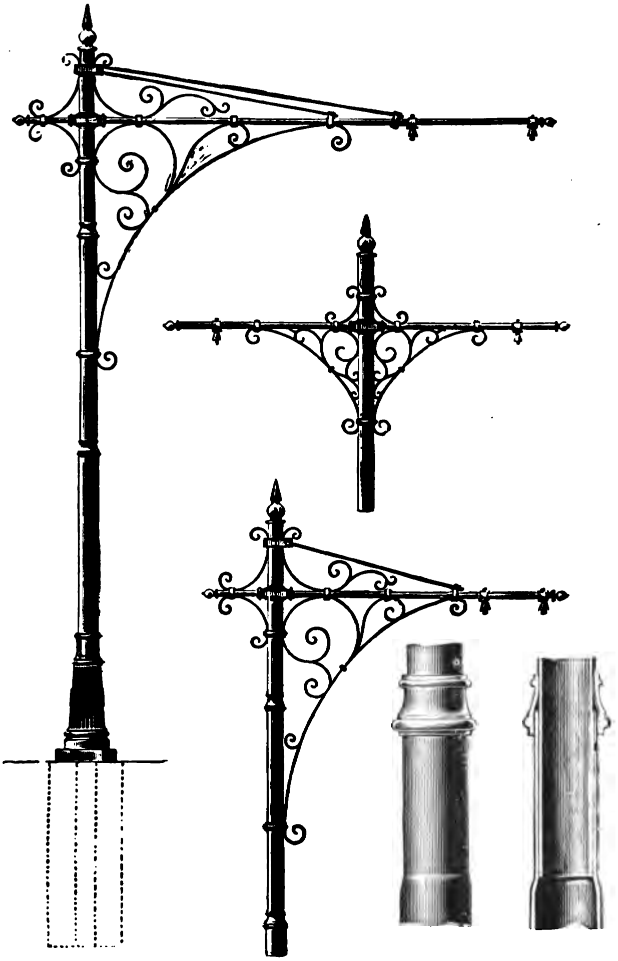


Fig. 51.

00 or 000 S.W.G. The wearing away of the copper is very slight, such wear taking place mostly at curves and at switches. There is of course more wear

on a side line construction than on a line placed over the middle of the track, for the reasons already explained.

The cross or span wires used in the support of the trolley line on side pole construction from each side of the street, are generally composed of galvanized iron wire, galvanized steel, or galvanized iron stranded wire; the size usually used is about 7 No. 12 or 7 No. 14 stranded. The great disadvantage of galvanized iron and steel span wires is their liability of rusting, and of the skin cracking and peeling off. The best material to use for span wires is silicon bronze; it does not rust; this wire is not much used, however, on account of its cost. Guard wires to protect the trolley line are generally made of galvanized iron or steel about ⅛ inch in diameter.

The insulating and supporting auxiliary apparatus, such as insulators, brackets, pull-offs, ears, strain insulators, hangers, frogs, crossings, etc., should be of the very best, designed and constructed on good sound mechanical principles, with a high factor of safety.

In the laying out and installing of the trolley wire or line, it is absolutely necessary that they should follow the curves on the track very accurately. For this purpose they are supported at the beginning and end of the curve by cross-wires, and in the curve itself by auxiliary wires radiating from the poles and fastened to the trolley wire at various points. Fig. 52 shows the method of planning such a cross-wire construction for a double track. We see that the trolley wire follows a polygon, the angles of which are held by special curve insulators and pull-offs, which will be illustrated and described further on. These insulated pull-offs are attached by wire stays to a mast of specially strong construction.

Another way of fixing a trolley wire curve is shown in Fig. 53; this is for a single track. On straight line work the trolley wire is put over the centre of the track, and in curve work on the inside of the curve, in order to reduce the speed of the trolley wheel, and also render the trolley wheel less liable to jump the

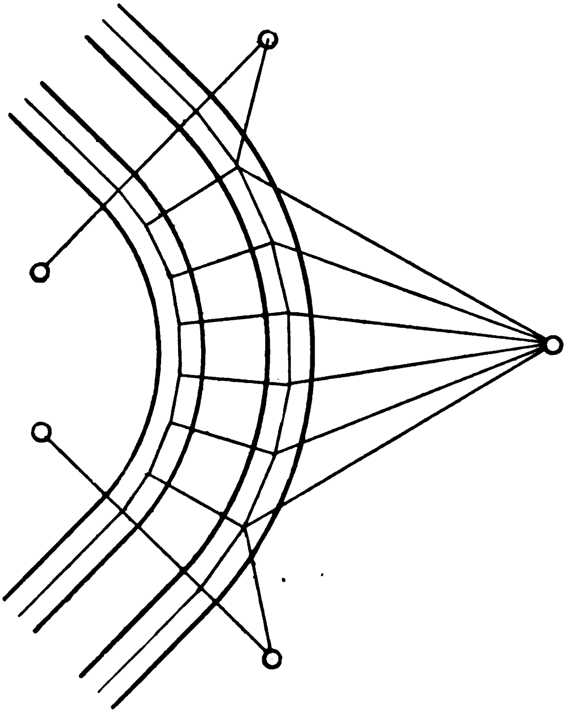


FIG. 52.

trolley wire. The distance of the trolley wire from the centre of the track depends upon the curvature.

Frogs or switches and crossings are used where two or more trolley lines branch or cross each other (illustrated later on); it is necessary to provide these

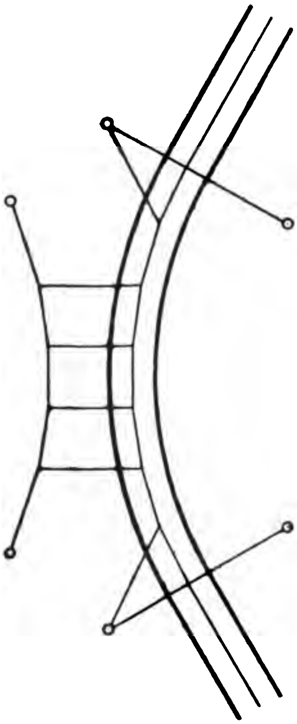


Fig. 53.

switches or ways so as to guide the trolley wheel across the meeting, dividing or crossing points. These frogs, etc., unless very carefully placed, will cause much trouble by reason of the trolley wheels jumping off the wire. The frogs should always be supported by span wires, and not simply rely for support on the trolley wire, because there is more weight, strain and jolting at the crossovers than there is on the straight line.

If the angles between the diverging tongues of the frogs be not the same as those of the trolley lines, the tongues should be bent so as to make the same angle. Frogs are often furnished with lugs attached to an insulating truss, which is held by guy wires, and prevents the frogs tilting. Frogs should not be secured until the trolley wire is in its proper position. When the height of the trolley line above the ground is between 18 ft. 6 in. and 20 feet the proper place for the frog can be found in the following manner. Let A B C D F represent the track in Fig. 54; then O represents the intersection of the right lines bisecting the angles B C D. The frog should be placed directly over O. This throws the main and branch lines a few inches out of centre, and it is the secret of making the frog work successfully. If the trolley runs off at a switch or frog, it should be chalked and the car run under it a few times, when the place where it runs off will be located.

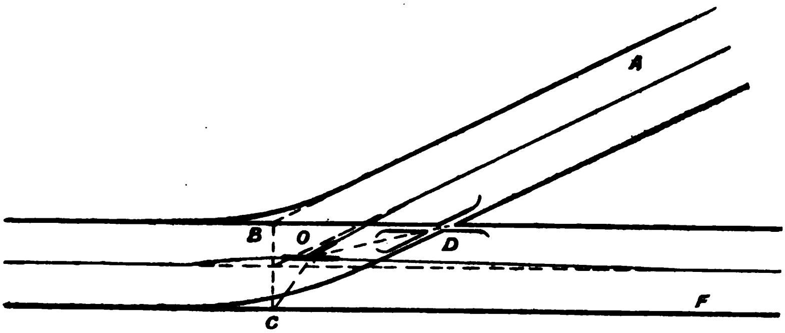


FIG. 54.

In the laying out of poles the distance between them depends upon circumstances; generally speaking, from 100 to 120 feet is the interval on straight line work. They should be closer together on curves, and if possible a pole put at each end of a curve, also a pole at the beginning and end of the line to which to anchor the trolley line. The conductors for overhead trolley lines as now widely and generally used are of circular cross-section.

CHAPTER VI.

OVERHEAD CONSTRUCTION AND EQUIPMENT.

THE first part of overhead line construction and equipment is the placing in position and setting of the poles; this necessitates them being securely planted in the ground; for this purpose a hole has to be dug and the pole set in a permanent and substantial foundation. The holes themselves ought to be dug to a depth of from 6 to 8 feet, the variation in depth depending upon the nature of the ground; in ground of a rocky formation 6 feet is generally quite deep enough, while in soft dirt the depth should be 8 feet. After the hole is prepared and the earth excavated to the proper depth, there should be placed at the bottom of the hole (before the pole is planted) as a foundation foot, a disc of sheet steel about 15 to 18 inches in diameter and about ½ inch thick (see Fig. 55); this prevents the pole sinking into the ground (when soft) and also, in the case of hollow iron poles, prevents the earth travelling upwards in the interior of the pole.

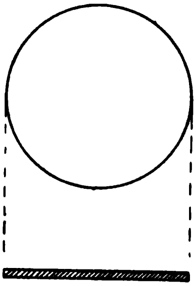


FIG. 55.

After the foundation plate or foot is placed in position, the pole may be planted by rearing it off the ground by means of a portable jib crane which can be moved from place to place on a truck, or it may be reared, by rearing ladders; the crane method is the safest and most practical.

If the pole is of wood it ought to be well tarred or pitched on the butt end before it is planted, and if of iron well tarred or painted. After being planted and set in position with its proper "rake" or slant, it should then be surrounded with good concrete, thoroughly rammed in tight so as to make a solid and substantial foundation (see Fig. 56).

In side pole construction, the poles, if of iron, would require a "rake" from the street of from 4 to 6 inches, in a height of from 20 to 25 feet; with wooden poles the rake would be about double, because the latter are more flexible and their bases are more apt to give a little. The general rule is for iron poles a rake of about $\frac{5}{16}$ inch to every foot of length above the ground, for wooden poles at least twice as much. Corner posts should have an additional rake of from 2 to 4 inches; poles at each end of a line should be extra heavy, and planted in a foundation of at least 7 feet of concrete, and have a rake of from 9 to 12 inches, and if necessary be suitably stayed.

In centre pole construction it is not necessary on straight line work to give the poles any rake; they are planted vertically. After the poles are properly planted and the holes filled up, the foundation should be allowed to become thoroughly set; after this the poles should be armed or bracketed and the span wires (if we are considering side pole construction on each side of the street) attached thereto and thoroughly tensioned and

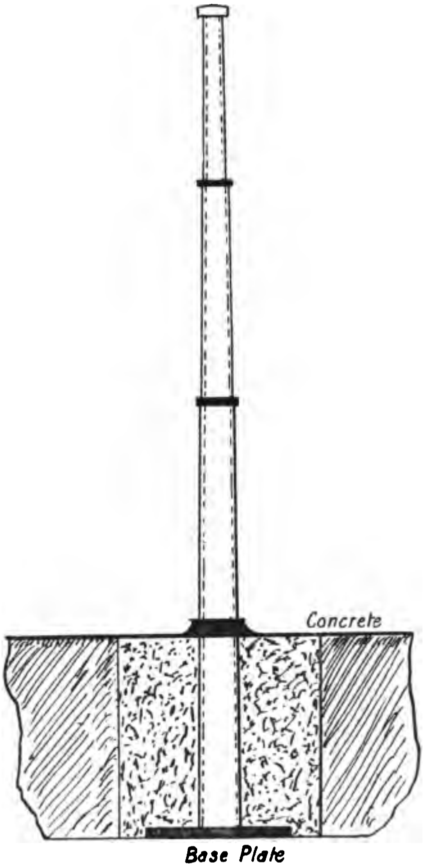


Fig. 56.

stretched. In this case, 7 No. 14 stranded galvanized steel wires would be used (see Fig. 46). These trolley wire spans should be tensioned up to between 400 and

600 lb.; they can be tensioned and adjusted by means of a turnbuckle; on very long stretches or spans it sometimes becomes necessary to give them more tension. The spans should, however, in every case be as loose as steadiness and appearance permit, as the greater the tension the greater is the liability of breakage.

After the trolley spans are stretched the guard wire spans should be put up, and the tension on them should be about 100 to 150 lb. The guard wire spans are for the purpose of supporting the guard wires, which are erected over a trolley line to protect it from any broken telegraph or telephone wires or branches of trees that might possibly come into contact with the trolley wire and short-circuit it. The guard wires are placed above and parallel to the trolley wire (see Figs. 44, 57, 58, 59, 60).

When there is only one trolley wire to protect, two guard wires are placed above it, one on each side, the distances being about 18 inches above, and from 12 to 18 inches on each side. In the case of two trolley wires the general practice is to stretch three guard wires, one on each side and one over the centre trolley wire, or midway between the two trolley wires. The size of wire recommended is No. 6 or No. 7 S.W.G., or still safer and more substantial a stranded galvanized steel wire of 12 No. 16 strands; this latter has been adopted at Cardiff. Galvanized steel wires have the inherent weakness of rusting and corroding, especially if erected in chemically-laden atmospheres.

In previous years the guard wires were thoroughly insulated from all earth connections, but recently the general practice has been to efficiently earth the guard wires at regular intervals. When the guard wires were insulated and any falling conductor electrically connected the guard wire and "live" trolley line together, the guard wires instantly became charged with a current of electricity, which was not only a very great source of danger to passing human beings and animals, but has been known to set fire to telephone stations, wherein were either no protecting fuses or inefficient ones. When the guard wires are earthed, the short piece of contact-making fallen wire is expected to melt instantly, and the street end thereof to fall harm-

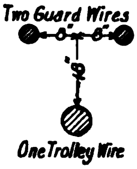


FIG. 57.

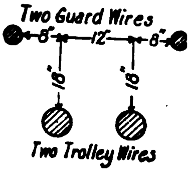


FIG. 58.

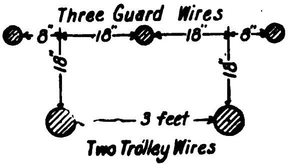


FIG. 59.

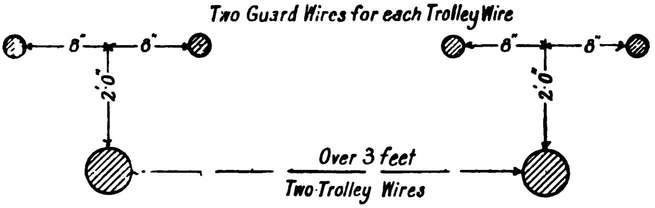


FIG. 60.

lessly to the ground. The author is of opinion that silicon bronze wire is much superior for guard wires, for the reason that it is stronger for the same size, has greater conductivity, does not rust, and is non-corrosive. Guard wires are very apt to become broken owing to the fact that when the trolley pole "jumps" the trolley line, it is likely to foul or strike the guard wire and break it. In Figs. 57, 58, 59 and 60 are some suggestions relating to the placing of guard wires over trolley wires; they represent respectively—in Fig. 57 two guard wires over one trolley wire; in Fig. 58 two guard wires over two trolley wires not over 12 inches apart; in Fig. 59 three guard wires over two trolley wires not over 3 feet apart; and in Fig. 60 two guard wires for each trolley wire when the latter are over 3 feet apart.

The supplying or feeding of the current to the trolley line is not done by connecting the power station supply directly to the trolley line itself, but the current is carried over the system by means of feeders (insulated copper conductors) which are connected to the trolley line at regular intervals.

When the line is long it is advisable to divide it into sections, usually about every half mile, and supply each section with its own current from the feeders, which feeder circuits are connected to the trolley line through switches, for the purpose of entirely disconnecting any section of the line, providing it becomes damaged or in case of repairing, etc.; each half mile section of the trolley line is entirely disconnected (electrically) from the other sections; it is only continuous mechanically, and each section is insulated from the next half mile section by means of what are known as section insulators (illustrated later on). To these section insulators the trolley line feeders are electrically and mechanically connected so as to feed their own section.

The advantages of dividing the line into sections are obvious. Supposing the line were 20 miles long and continuous, supplied with current at one end, under heavy traction load the waste of energy would be excessive, which is equal to the square of the current multiplied by the resistance (watts lost $= C^2 \times R$), the energy lost increasing as the current squared. There would also be too great a drop in voltage, which is equal to the current multiplied by the resistance (volts $=$ C in amperes × resistance in ohms); again, a break in it would throw out of action all the cars, except those between the point of breakage and the power station, whereas when the trolley wire consists of several lengths insulated one from the other by means of electrical disconnections at section insulators, only the section where a break occurs is put out of service, so that electrically each half mile section is entirely independent.

The feeders which carry the energy to supply the trolley lines, may be run either overhead or underground; if installed underground they are generally run in conduits of some description, and a branch feeder is taken off through switches and street boxes, and run up the pole and then connected into the section of the line. The underground system is adopted mostly in city and town work, but for light railway and country work it is the more economical and easier to carry the insulated "feeder" conductors overhead on insulators on the same poles as the trolley lines.

At each half mile section a branch conductor is tapped off the feeder and connected both mechanically and electrically to the trolley wire. One great advantage of tapping the feeder circuit into the trolley line at regular intervals, is the fact (often overlooked and neglected) that the sectional area of the copper in the feeder may be reduced somewhat as we proceed section after section away from the power station supply, owing to the fact that in a well organised system of traffic or car load on different sections of the line, the cars will be travelling to or from the terminus at nearly equal distances apart. Under the above conditions there will not be as much current carried at the far end of the feeder conductor as there will at the beginning; or in other words, the conductor current in the feeder will grow less and less as we proceed from the source of power supply. For this reason the cross section of the "feeder" conductor can be somewhat reduced, thus saving some initial outlay as regards weight of copper.

After the spans are put up, the next thing is to locate the ear bodies or trolley wire insulators, which differ in shape according as they are for straight line or curve work; also the frogs or switches, crossings, section insulators, etc. (some types will be illustrated later on). Then the trolley wire is securely anchored at one end of the line and reeled out for about 750 to 1000 feet; temporary slings of iron wire are then put over the span wires, and the trolley wire is raised up on a tower wagon (see Fig. 61) and hung in these slings. Straining clamps have to be fixed to the trolley wire, which should then be pulled up tight by four or five men with double block and tackle and fixed to a temporary anchor. The permanent anchor is then pulled up tight and fixed to a pole, so as to maintain the tension put upon the trolley wire.

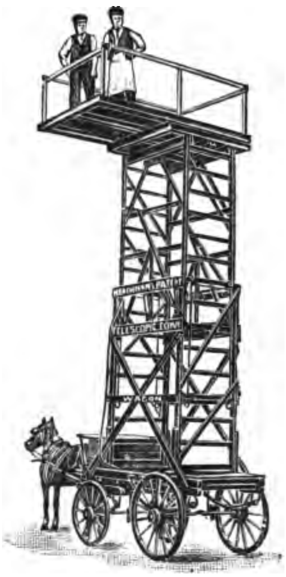


Fig. 61.

When a curve is reached the trolley wire should be pulled up tight to this point and anchored, then run round the curve, allowing the slack necessary to construct the curve. On the curves the slings must be attached to the span wires or pull-offs, so that they cannot slide along them. The trolley wire should be put a little inside of its final position, and pulled comparatively tight, and then it must be anchored both ways at the end of the curve. Double anchors ought to be placed about every 500 to 800 feet on straight line work and also at each end of every curve. Figs. 62 and 63 illustrate a method of setting the anchors both for single and double line work. A single anchor need only be used at the end of the line.

One of the most important things in overhead construction is the setting of the anchors, and if badly done this is very liable to cause great trouble. For anchoring, the same kind of wire that is used for the spans can be utilised, and is generally pulled about half as

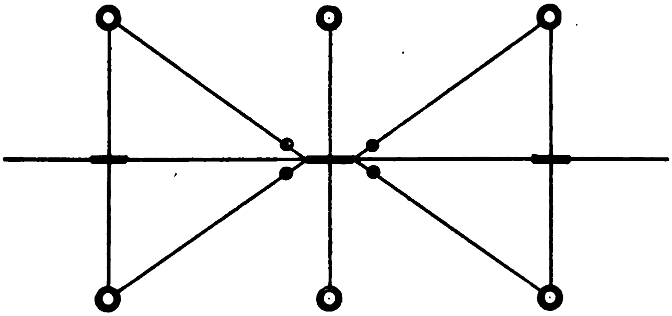


FIG. 62.

tight as the spans. Insulators should be put into each anchor about 18 inches or 2 feet from the point where it is fixed to the anchor ear.

After the ear bodies have been located and the

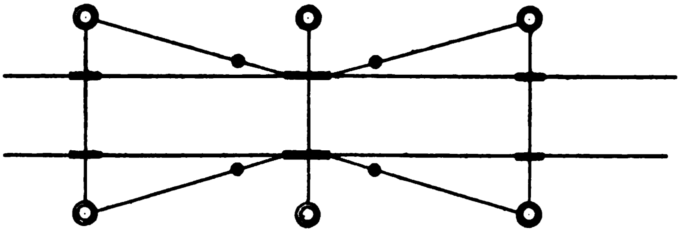


FIG. 63.

trolley wire temporarily suspended in the slings or riders fixed to the span wires, the trolley wire has next to be permanently attached to the ear which is to secure and hold it: this will generally be done by soldering. Now it is not advisable to have any twist or torsion in the trolley line, and, owing to the fact that it is a difficult operation to solder the wire into the ear when the ear is in its erect position, it becomes necessary to do so when it is upside down; if this latter is done the result is that when twisted into its erect position it puts a half twist in the trolley line at every ear suspension; this is very bad and undesirable from a practical point of view, so the method adopted is to give the trolley wire a half twist and hold it in that position by means of a heavy clamp (see Fig. 64) and solder the ear on upside down. When the operation is completed the clamp is taken off and the ear comes into its erect position without there being any twist or torsion in the trolley wire.

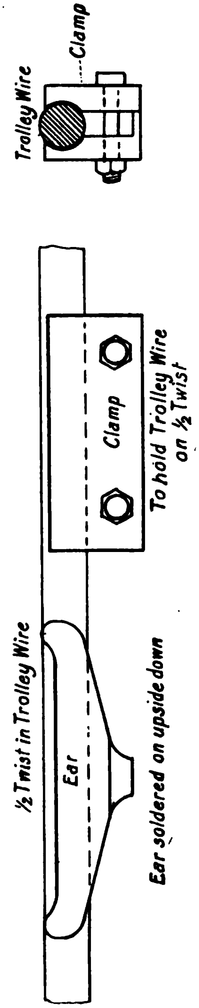


FIG. 64.

In the soldering of the wire to the ear it is highly important that the tension should be taken off the line at each side of the ear, and that in the soldering the wire should not be softened too much with the heat applied; if these precautions are not taken, the wire may, owing to the effect of the great tension, and the softening effect of the heat, become stretched, reduced in diameter at that position and greatly weakened, and to this cause is generally due the breaking of the wire at the ear.

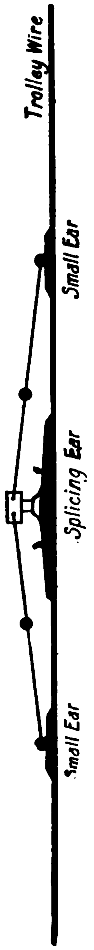


Fig. 65.

Great care should be taken not to nick into the trolley wire with pliers, otherwise the "skin" strength is destroyed. After the ear is properly soldered or mechanically connected, it is attached to the hanger and insulator, and all is in position and complete; all joints in a trolley line should be made at a proper splicing ear, and never in the middle of a span. They are always a great source of weakness and danger if not properly made and mechanically strong.

A good method of taking some of the strain from off the splicing ear is shown in Fig. 65. In curves it is very advisable to use long ears, from 2 to 3 feet long, which bend evenly in conformity with the curves throughout their whole length. Straight line ears should not be under 15 or 18 inches long. Section insulators should always be placed wherever possible on the straight and flat, because they are not designed to take any side or lateral strain, and also because the current must be shut off at section insulators to prevent "arcing." In the span wire across from pole to pole, there should be a turnbuckle at each end, also an insulator at each end close to the pole in each case.

Where the guard wires are earthed directly on to the iron poles, it is a good idea to thoroughly earth the pole by connecting it by means of a long copper bond to one of the track rails. By this method we get an earth of comparatively low resistance. In every detail of overhead equipment there should be allowed a wide "factor" or margin of safety. The trolley wire is usually suspended at a height of from 18 to 19 feet from the surface of the rails or road. It must not be less than 17 feet; the average height generally is about 18 feet at the lowest point, which is in the middle of the span; for here the dip is greatest, due to the sag of the wire.

The sag will depend upon the weight of the wire, upon the length between the points of supports (which is generally from 100 to 125 feet), and upon the tension of the wire; the dip and sag increase with increase of temperature due to the expansion of the wire. The actual curve in which the trolley wire hangs is a catenary, but being very flat, the curve may, for purposes of calculating dip and tension, be treated as a parabola. We must now consider the mechanical strains to which an overhead line may be subjected, and the laws which govern them. When a wire is suspended between two poles, the tensile strain tending to break the wire is due partly to its own weight and partly to the pressure of the wind on its surface; it is greater as the span or distance between the poles is increased, and less as the sag or dip is increased. The law which determines the strain or tension at the point of support is as follows:

$$T = \frac{L^2 w}{8d} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$d = \frac{L^2 w}{8T} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where T = tension on the wire in lb.
L = distance between supports in feet
w = weight in lb. per foot of wire
d = dip or amount of sag in feet.

Introducing three other factors:

l = actual length of wire in feet between supports
t = temperature
θ = change of temperature,

we have

$$l = L + \frac{8d^2}{3L} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$d = \sqrt{\frac{3Ll - 3L^2}{8}} \quad . \quad . \quad . \quad (2)$$

Example I. $L = 100$ feet. $d = 100\cdot106$ feet.

$$\therefore \quad l = 100 + \frac{8 \times 2^2}{3 \times 100} = 100 + \cdot106$$
$$= 100\cdot106 \text{ feet.}$$

If a change of temperature of 50° Fahr. takes place, this length will alter.

Let the temperature rise = 50° Fahr.

Taking the coefficient of expansion at $\cdot 00001$ per degree Fahr.:

$$
\begin{aligned}
l &= 100{\cdot}1\,\{1 + \theta \times {\cdot}00001\} \\
&= 100{\cdot}1\,\{1 + 50 \times {\cdot}00001\} \\
&= 100{\cdot}1 \times 1{\cdot}0005 \\
&= 100{\cdot}156 \text{ feet.}
\end{aligned}
$$

$$\therefore \quad d = \sqrt{\frac{3\,\{100{\cdot}156 \times 100 - 100^2\}}{8}}$$

$$= \sqrt{\frac{3 \times 15{\cdot}6}{8}} = \sqrt{5{\cdot}85}$$

$$= 2{\cdot}41 \text{ feet.}$$

Original dip was 2 feet; therefore there is an increase in dip of 4·92 inches.

Example II.

Let $L = 100$ feet; $w = {\cdot}5$ lb. per foot length
$t = 50°$ Fahr. $d = 2$ feet.
Find T at 50° Fahr., and at 10° Fahr.

At 50° Fahr. $$T = \frac{L^2\, w}{8\, d}$$

$$= \frac{100^2 \times {\cdot}5}{8 \times 2} = \frac{5000}{16} = 312{\cdot}5 \text{ lb.}$$

At 10° Fahr. the dip would be $= 1{\cdot}62$ feet;

$$\therefore \quad T = \frac{100^2 \times {\cdot}5}{8 \times 1{\cdot}62} = \frac{5000}{19{\cdot}96} = 386 \text{ lb.}$$

If the wire is 0000 gauge, or 0·4 of an inch in diameter, the cross sectional area = 0·1256 sq. inch.

∴ Tension in first case

$$= \frac{312 \cdot 5}{0 \cdot 1256} = 2490 \text{ lb. per sq. inch.}$$

Tension in the second case

$$= \frac{386}{0 \cdot 1256} = 3075 \text{ lb. per sq. inch.}$$

Sag in span of 125 feet of 1–0 hard-drawn, copper trolley wire with tensions from 200 to 2000 lb.:

Tension in Pounds.	*Sag in Inches.*
200	34·75
250	28·2
300	23·7
350	20·5
500	15·0
750	9·5
1000	7·4
1500	5·0
2000	3·8

A rough-and-ready manner of tensioning the trolley wire, sufficiently near generally for all practical purposes, is to allow a sag of 10 or 12 inches in a 120-foot span. When the line is completed the poles and other line material needing it should be given one or two good coats of paint to keep the parts from rust.

To divide the trolley line into sections, a section insulator is used, Fig. 66 representing one of the forms generally made use of. The tapping wires from the feeders (either overhead or underground) are attached thereto.

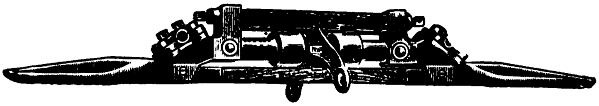


FIG. 66.

For the purpose of suspending the trolley wire from bracket arms, and span or cross wires, several methods are shown. Each attachment may be usually divided into (1) the ear to which the trolley wire is directly attached; (2) the hanger; (3) the insulating portion; and (4) the span wire grip.

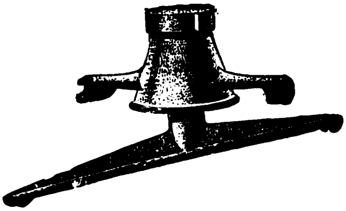


FIG. 67.

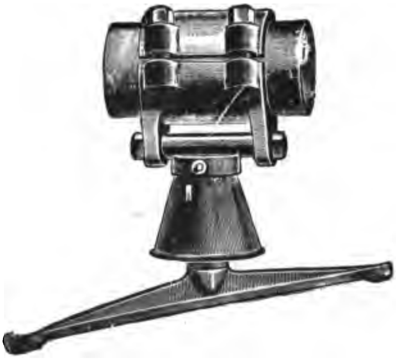


FIG. 68.

Fig. 67 represents a Straight Line Insulator.

Fig. 68 is a Bracket Arm Hanger, Double insulation.

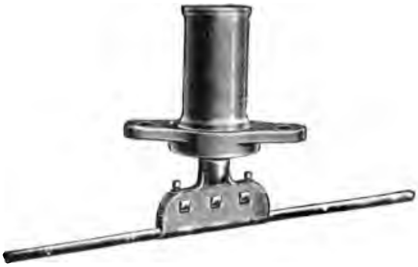


FIG. 69.

Fig. 69 is a Spring Bridge Insulator.

Fig. 70 a Double pull-off generally used for curve line work. Fig. 71 is a Single pull-off used for the same purpose.

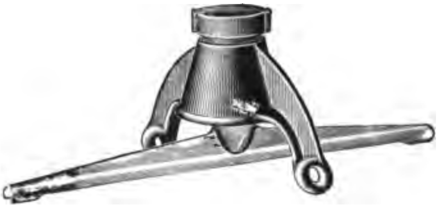


FIG. 70.

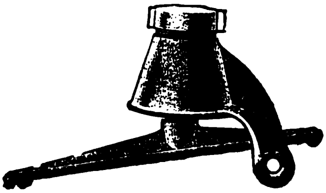


FIG. 71.

Fig. 72 is a Straight Line Ear.

Fig. 73 is an Anchoring Ear.

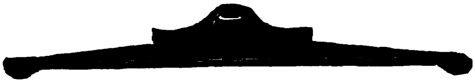


FIG. 72.

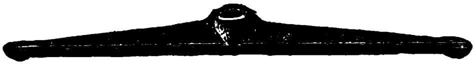


FIG. 73.

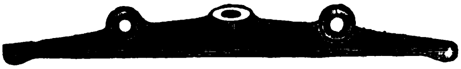


FIG. 74.

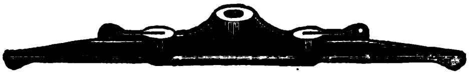


FIG. 75.

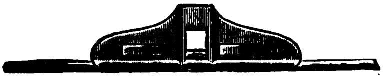


FIG. 76.

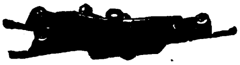


FIG. 77.

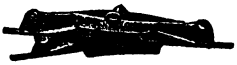


FIG. 78.

FIG. 79.

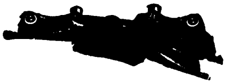


FIG. 80

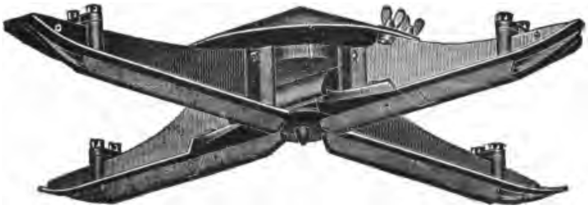


FIG. 81.

Fig. 74 is a Feeder Ear.

Fig. 75 is a Splicing Ear.

Fig. 76 is a "Badger" Mechanical Ear.

Where one trolley line crosses another line it is necessary to provide switches or paths for the trolley wheel, usually called frogs.

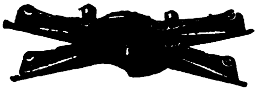


FIG. 82.

Fig. 77 illustrates a Right-hand Frog.

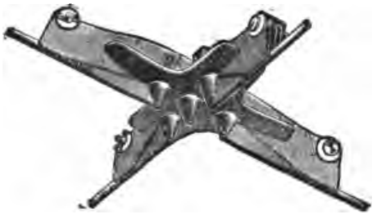


FIG. 83.

Fig. 78 illustrates a Left-hand Frog.

Fig. 79 illustrates a Y Frog.

Fig. 80 illustrates a Three-way Frog.

Figs. 81, 82 and 83 are Crossings.

FIG. 84.

FIG. 85.

For insulating and straining the trolley wire and span wires, a variety of devices are used.

Fig. 84 is a Straining Clamp used in erecting.

Fig. 85 is an Insulating Terminal Clamp made of bronze with insulation.

Fig. 86 is an Insulated Turnbuckle used for anchoring and straining to posts.

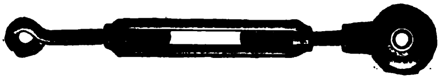


Fig. 86.

Figs. 87 and 90 are two Globe Insulators for anchoring and straining.

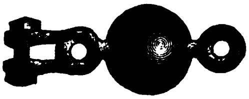


Fig. 87.

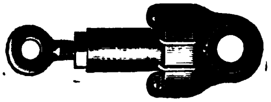


Fig. 88.

Fig. 88 is the Brooklyn Strain Insulator, which also serves as a turnbuckle, each one giving an adjustment of some 3 inches when in position. The materials are of bronze and "Ætna" insulation.

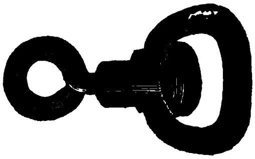


Fig. 89.

Fig. 90.

Fig. 89 is a very heavy insulated terminal used at trolley wire ends.

CHAPTER VII.

NOTES AND DETAILS ON MATERIALS IN THE CONSTRUCTION AND EQUIPMENT OF VARIOUS TRAMWAY UNDERTAKINGS.

MANCHESTER CORPORATION TRAMWAYS.

Permanent Way.—The gauge of the track is 4 ft. 8½ in. The rails are of Bessemer steel, 60 feet long, and weigh about 102 lb. per yard. The width of the flange is 7 inches, and the depth over all is 7 inches; the rail groove is 1⅛ inch deep and 1⅛ inch wide. The tread of the rail is 2¼ inches wide. The fish-bolt holes in the web of the rail are 1⅛ inch diameter. The fish-plates are of Bessemer steel, 24 inches long, and weigh 64 lb. per pair. The diameter of the fish-plate bolts is 1 inch, and the fish-plates are bolted through with six bolts and fastened with patent lock-nuts. The tie-bars are of Bessemer steel, about 5 feet long, and tie the rails every 10 feet apart.

The concrete foundation placed under each rail is about 8 inches deep and 18 inches wide. The composition of the cement concrete is 4 parts broken stone, 2 parts sand, and 1 part cement. The rail filling is composed of 6 parts sand to 1 of cement. The rails are floated under and around the flanges with liquid cement.

The rails are bonded at each joint with one inside flexible copper bond, 8½ inches long, and two solid copper bonds on the outside of the fish-plates 30 inches long. The rails are also well bonded at points, crossings, etc., and are cross bonded every 200 feet. The roadway is paved with Welsh granite setts 3 to 3½ inches wide and 9 inches long (10 per cent. are 4 to 5 inches long), the joints are filled with limestone chippings or shingle, and grouted with pitch.

Overhead Equipment.—The overhead equipment is constructed both on the centre pole and side pole with span wires; the poles used are made of steel in three sections, planted in cement concrete foundations about 6 feet deep; the trolley wire is placed at a distance of about 18 ft. 6 in. above the surface of the roadway. The trolley wire has a diameter of 0·4 ($\frac{4}{10}$) of an inch. Its weight is 2557 lb. per mile. Conductivity 98 per cent. (by Matthiessen's standard). Resistance 0·337 ohm per mile. Stress 23 tons per square inch. The span wires are composed of galvanized mild steel, and the sizes used are 7 No. 16, 7 No. 14, and 7 No. 12 S.W.G. stranded together; the breaking stress is 35 tons per square inch. The guard wires are of 7 No. 16 S.W.G. stranded cable made of galvanized mild steel.

Conductivity Test for Bonds.—The sectional area of the bonds is 0·166 square inch.

1. For all except internal bonds: The bond is immersed in water at a temperature of 60° Fahr., and a steady continuous current of considerable magnitude is passed through it, and also through a standard

resistance connected in series with it. The fall of potential between two points 24 inches apart, neither point to be less than 5 inches from the end of the bond, is measured, and also the fall of potential across the standard resistance; from these measurements the resistance of the bonds between the points is calculated, which resistance shall not be more than ·0001 ohm.

2. For internal bonds: These will be tested in the same manner as in (1), but the points between which the difference of potential is measured, will be taken on the solid ends of the bonds, and the resistance must not exceed 0·000035 ohm.

Brighton Corporation Electric Tramways.

The concrete bed of the track is of Portland cement concrete, 6 to 1, and of the depth of 6 inches; the rails are of the girder type, 6 inches high with a 7-inch base, and weigh 101 lb. per yard; the length of the rails being 36 feet, with a small proportion 30 feet. Extra strong fish-plates, weighing 46 lb. per pair, were used, with 20-inch steel sole-plates under the rail joint, resting on a 6-inch steel girder sleeper running transversely to the rails (see Fig. 32).

The method adopted for laying the permanent way was as follows:—The excavation being taken out to the necessary depth for the concrete bed, and also the trenches for the steel sleepers, the latter were bedded on a 6-inch foundation of cement concrete; the rails were then laid in position and brought true to the required level and bolted up. Then the concrete bed for the permanent way was put in, the effect of this being to securely anchor down the rail joints with the full weight of the concrete substructure. An even bed for the reception of the wood paving was provided in fine concrete in the proportion of 3 parts sharp sand to 1 of Portland cement, wood paving being carried out throughout. The wood selected was American red gum blocks, which were dipped in hot pitch when laid, and then grouted up with hot pitch. The rail joints were double bonded with 0000 copper bonds. The steepest gradient on the system is 11 per cent.

The overhead construction was adopted with side and centre poles. The poles are of drawn tubular steel, with bracket arms of 2½-inch steel tubing and ornamental wrought-iron scrollwork of elegant design. Proper provision has been made by guard wires for the protection of the telegraph and telephone wires which cross the track.

LANCASTER CORPORATION ELECTRIC TRAMWAYS.

In the road construction, the excavations generally were 12 inches deep, allowing a 6-inch rail section to be used upon a 6-inch bed of concrete. The rail joints are supported by anchor sole-plates of 60 lb. weight, and 24 inches long, inverted and riveted to the bottom of the running rail (see Figs. 33 and 34). The weight of the rails is 90 lb. per yard, and they are 60 feet long. Each rail joint is bonded with two 0000 copper bonds. The steepest gradient is 1 in 10, with a radius of 80 feet. The sharpest curve on the track is 60 feet.

Power is transmitted by the overhead trolley system, side bracket poles being used throughout. These poles were planted in 6 feet of concrete. The trolley wire is 000 hard-drawn copper, and is supported from the bracket arms by flexible suspension with Ætna insulators. Where necessary, guard wires are provided. A section feeder box is placed at every half-mile of track, fitted with marble panels carrying four switch fuses, two feeder switches, lightning arrester, choke coil and telephone plug connection. The tramway feeder cables are laid in the centre of the track in earthenware conduits.

BOURNEMOUTH CORPORATION TRAMWAYS.

The track is laid to a gauge of 3 ft. 6 in.; several of the routes are double track, but there are portions laid single with turnouts. The rails weigh 100 lb. per yard; they were laid on a bed of concrete 6 inches thick, and the rail joints are made with both fish-plates and sole-plates.

The overhead equipment includes both bracket arm and span wire construction; sectional steel poles are used, from 7 to 9 inches diameter at the base, 4½ to 5½ inches at the top, and 31 feet long. The bracket arms are of steel tapered tube. The trolley wire is of ·384 inch hard-drawn copper.

CAMPS BAY, CAPETOWN AND SEA POINT TRAMWAYS.

The gauge of the track is 4 ft. 8½ in. The rails are of the girder section, weighing 90 lb. per yard. They are laid on a concrete foundation, a strip of concrete 6 inches deep and 18 inches wide, composed of 5 to 1 Portland cement, being laid under each rail. Karri wood paving has been laid for a width of 1 ft. 10 in. on each side of the track, and a 9-inch toothing course along the inner side of each rail. The rail joints are each bonded with two 6/0 S.W.G. copper rail bonds. Gradients of 1 in 9 are encountered.

The side arm system has been adopted for the overhead equipment, the trolley wire of No. 0 S.W.G., being carried at a height of 18 ft. 6 in. above the rail level. The poles are of mild steel, tapering from 7 inches at the base to 3½ inches diameter at the top. The arms vary in length from 6 ft. 6 in. to 15 feet, according to the width of the road, the average distance of the furthest trolley wire from the centre of the track being 10 feet.

CARDIFF CORPORATION TRAMWAYS.

The sharpest curve on the system is of 40 feet radius, and the steepest gradient 1 in 20. Girder type of rails have been used, having a weight of 100 lb. per yard. The rails are 45 feet long, and 6¼ inches deep, with a 7-inch flange. The groove of the rail is 1¼ inch wide by 1¼ inch deep. The rails are laid on a concrete bed 11 inches deep and 18 inches wide, the depth of the concrete under the other portions of the track being 8 inches. The rail joints are made by fish-plates weighing 64 lb. per pair, with six 1-inch bolts and patent lock-nuts. The joints are further secured by sole plates 2 ft. by 11 in. by ½ in. thick, secured by four single and two double clips, with ¾-inch bolts and nuts. The depth of the rails being 6¼ inches, and that of the paving bricks only 4 inches, enables the rails to be buried in concrete to a depth of 2¼ inches.

The track is paved almost entirely with wood blocks, with composition blocks between the tracks, where centre poles are used. The wood blocks are jarrah wood and red gum. To reduce the wear and tear on the wood blocks at the sides of the rails, chilled iron paving blocks are laid alternately with the wood blocks. The track is double-bonded at each joint with a copper bond, and a plastic bond; it is cross-bonded about every 80 yards.

The overhead equipment is flexibly suspended, both centre pole and side pole with bracket arms and span wire construction being used. The hangers are made of best gun-metal, with ¾ inch insulated bolts. None of the ears are less than 18 inches long and vary in length up to 36 inches. The span wire consists of seven strands of No. 12 S.W.G. galvanized steel wire, whilst the guard wires are of 12 No. 16 strands.

PORTSMOUTH ELECTRIC TRAMWAYS.

The gauge of the track is 4 ft. 7¾ in., and the rails of the steel girder type weigh 90 lb. per yard, in lengths of 40 feet. The fish-plates weigh 130 lb. per pair, being combined with sole-plates. The rails are double-bonded with copper bonds 30 inches long, and are cross-bonded every 40 yards. The foundation of the track consists of 6 inches of concrete, varying to 13 inches in places, upon which the rails are laid direct.

The overhead equipment was carried out on both the span wire and the bracket systems, much of the track being equipped with single-arm bracket poles. The trolley wire is double throughout, of 00 B. and S. gauge, and is placed centrally over the track. The system is divided into sections each half a mile long, supplied with current by 14 feeders, which are mostly drawn into conduits.

SALFORD CORPORATION TRAMWAYS.

The gauge of the track is 4 ft. 8½ in. The maximum grade of the track is 1 in 20, and the sharpest curve 41 ft. 6 in. in radius. The track is laid on a concrete bed, and consists of 60 feet girder rails, weighing 103 lb. per yard. The roadway is paved with granite setts. The joints are double-bonded with flexible copper bonds, equivalent to 0000 S.W.G. in cross section, and the trucks and rails are cross-bonded every 120 feet.

The overhead equipment is carried out both with span wire construction, and centre pole work fitted with flexible suspension. The guard wires are 7 No. 16 stranded galvanized steel cables; the trolley wire is of hard-drawn copper; the poles are made of steel. The tramway feeders are drawn into ducts; they are 18 in number, ranging in cross-section from 0·75 to 0·25 sq. in. The trolley line is divided into half-mile sections, the switches being placed in section boxes.

GREAT YARMOUTH TRAMWAYS.

The rails weigh 90 lb. per yard, and are in lengths of 45 feet. The foundation consists of a concrete bed 6 inches thick, on which the rails are laid to a gauge of 3 ft. 6 in. The rails are tied every 6 feet, and cross-bonded at intervals of 120 feet. The steepest grade is 1 in 27, and the sharpest curve 48 feet radius. The bonds are both of the copper bond and plastic type. The trolley wire is ·409 inch in diameter, and is suspended from brackets carried on side and centre poles.

WALLASEY TRACTION SYSTEM.

The steepest gradient is 1 in 14, the sharpest curve having a radius of 45 feet to the inside rail. All curves were laid "tight-to-gauge," and this is said to have been found of much advantage in working. Most of the curves are of at least 75 feet radius. To form a bed for the rails, the road was excavated, and 6 inches of concrete were laid down. The rails were laid on blocks of concrete about 12 inches square, and the bed-concrete was then brought up to the rails. Between the rails, and for 18 inches on each side, the track has been paved, generally with granite. The rails are 60 feet long, weighing 98 lb. per yard. The base of the rail is 7 inches wide, and the depth from face to underside of base is also 7 inches. Fish-plates weighing 64 lb. per pair were used, also a patent sole-plate weighing 34 lb. was used under each joint.

Tie bars were used every 7 ft. 6 in. The gauge is standard, 4 ft. 8½ in. Copper bonds and plastic bonds have been used at the rail-joints. A cross bond was introduced at every 100 feet. The points and crossings are bonded through, in addition to the bonding at the joints.

In the overhead equipment, side poles and brackets have been used generally to carry the trolley wires. The poles are three-section steel poles, 31 ft. 6 in. high, and weigh about 5 cwt. each. The brackets vary in length from 10 ft. 6 in. to 18 ft. 6 in. Two guard wires have been used above the trolley wires wherever necessary. All guard wires are earthed and bonded on the poles, and the poles are bonded to the rails. Two gauges of cold-drawn copper trolley wire have been used; one of 00 gauge is used for the car shed, while on the roads a wire of 000 gauge is used.

Glasgow Corporation Electric Tramways.

The track is laid with grooved girder rails, weighing 98 lb. per yard in 60 feet lengths. The rails are 7 inches high, with a base 7 inches wide, and are laid on a concrete bed 6 inches thick. The fish-plates are 31 inches long, and are fixed with eight 1 inch bolts. On curves the rails weigh 105 lb. per yard. The groove is 1¼ inch wide and deep, and the gauge of the track is 4 ft. 7¾ in. Each joint in the rails is bonded with two No. 0000 B. and S. solid copper bonds over the fish-plates fixed in the web of the rails, and two flexible copper bonds of the same gauge fixed on the foot of the rails.

The overhead equipment is carried out on the span-wire system with rosettes; the rosettes are of cast iron, with rubber buffers to diminish vibration. The trolley wire is of No. 00 B. and S. gauge, divided into half-mile sections. The span wires are of 7 No. 12 S.W.G. galvanized steel. The guard wires, which are earthed, are of No. 7 S.W.G. steel wire, with 7 No. 14 galvanized steel span wires. The trolley is of the "straight under-running" type, so that the trolley wire is directly over the centre of the track. Central pole construction is used in several parts. Bow-string (flexible) suspension is used, to avoid shock to the trolley.

EAST HAM ELECTRIC TRAMWAY.

The gauge of the track is 4 ft. 8½ in. No curves are of less than 40 feet radius. The whole of the track is laid with 87 lb. rails, double-bonded throughout, with 0000 S.W.G. copper bonds. The double track is laid upon a continuous bed of cement concrete, 6 inches thick, paved throughout to a distance of 18 inches outside the rails with granite setts, while in the single track the rails are laid on a continuous bed of concrete 18 inches wide by 9 inches thick, the surface being paved with granite setts 9 inches on each side of the rails, and the centre filled in with tarred macadam.

The overhead equipment consists entirely of side pole and bracket construction, the maximum length of any bracket being 18 feet. The poles, which are of the telescope joint type, are known as the No. 3 and No. 4 pole, the No. 3 having a length of 31 feet, weighing without the base, 990 lb., while No. 4 is of the same length, with a weight of 1321 lb. The trolley wires are No. 0 B. and S. gauge, tested to an actual breaking stress equal to 27·3 tons per square inch.

ISLE OF THANET LIGHT RAILWAY.

The track is mainly laid double, the gauge of which is 3 ft. 6 in. and wherever possible it has been laid interlacing in preference to single. The rails used weigh 83 lb. per yard; they are well bonded throughout by 0000 B. and S. gauge copper rail bonds. In the towns wood paving has been used; in other places ordinary granite paving at each side of the rail was thought sufficient.

The overhead wire is of No. 0 B. and S. gauge carried by ears and hangers supported from off mild steel poles built in three sections. Section boxes are placed every half-mile, being fitted with two main switches, four feeder-switches, pilot terminals, and a telephone.

LONDON UNITED TRAMWAYS.

The system consists almost entirely of double track. The rails are of steel of the very best quality. The weight of the rails is 92½ lb. per lineal yard, and they are rolled in 36 feet lengths. The bed on which the rails are laid consists of concrete 6 inches thick, composed of seven parts Thames ballast and one part Portland cement. This is covered with a floating of sand and cement about 2 inches thick, on which are laid the wood blocks, the joints being afterwards run in with pitch. The sand and cement floating is composed of four parts clean sharp sand and one part Portland cement. The fish-plates weigh 92½ lb. per pair, and are made of steel of the very best quality. The rails are double-bonded throughout. At every joint there are two copper bonds of 0000 B. and S. gauge, with cross bonds every 40 yards. The tramways are paved with hard wood jarrah blocks, tar-grouted and top-dressed with Portland cement.

Practically the whole of the "overhead" equipment is carried out on the "span wire" system. The side standards are formed of steel tubes, and three grades are used, able, when set 6 feet in the ground, to stand stresses of 700 lb., 1000 lb. and 1500 lb. respectively, applied 30 inches from the top, with a temporary deflection of not more than 6 inches; and stresses of 1200 lb., 1760 lb. and 2600 lb. respectively applied in the same manner, with a permanent set of not more than ½ inch.

These standards are set in 6 feet of concrete, which completely fills the holes dug to receive them, and which is thoroughly tamped down during the process of filling. The radial thickness of the concrete round the standard is 8 inches. The lower end of each standard rests on a cast-iron plate. The concrete used was composed of one part best Portland cement to five parts clean gravel or broken stone, mixed as required and used fresh. The standards are planted with a sufficient rake to compensate for the strain caused by the bracket arm and span and trolley wires when erected.

The trolley wire is hard-drawn copper wire of No. 0 B. and S. gauge, having a conductivity of 98 per cent. of pure copper. The diameter of this wire does not vary more than ·0004 inch; and the weight per 1000 yards is 960 lb. The maximum working stress will not exceed 2000 lb., and the breaking stress is 5000 lb. The entire route is divided into half-mile sections, and two section boxes are provided. This constitutes one of the most distinctive features of the system, as each trolley wire has its own feeder and distributor, and each of these can be disconnected at these section boxes.. The distribution is thus duplicated throughout, forming an ideal system, providing against breakdowns either in the cables or in the overhead equipment. The section boxes are all equipped with telephone plug-boxes. These are connected with a 16-line annunciator at the head office, which is also connected with the various departments in the offices, thus providing a complete system of intercommunication between the respective departments and all parts of the lines.

The object of this chapter has been to show the standard practice at present in vogue. In the author's opinion, no rails should be used of a less weight than 95 lb. weight per lineal yard, and the weights of rails chosen ought to vary (according to local conditions and circumstances) from a minimum of 95 lb. up to a maximum of about 120 lb. weight per lineal yard. As regards the trolley wire, it should be of hard-drawn copper of a minimum size equal to 00 B. and S. gauge. Guard wires should never be used of one solid wire, because if nicked or damaged it tends to break easily; all guard wires should be of stranded wire of not less than 7 No. 18 strands, and made of silicon-bronze. Span wires should all be stranded, of a not less size than 7 No. 14 gauge. The ideal materials for overhead line equipment, both from a practical, safe and durable point of view, are hard-drawn copper for the trolley wire, and silicon-bronze for all span wires, guard wires and turnbuckles; galvanized iron and steel possess the inherent weakness of the "skin" cracking and peeling off and rusting, thus becoming weak, with a great liability to break.

CHAPTER VIII.

TESTING AND MAINTENANCE OF ELECTRIC TRAMWAYS.

It is highly important and desirable to have a good means of localising faults on a tramway system. One of the best systems of testing (due to Mr. A. Johnston) is shown in Figs. 91 and 92, by which means the position of a fault can be found with a fair degree of accuracy and rapidity, the only delay being caused by the necessity to divide the reading on the testing voltmeter into the value of the testing current and then refer to a chart before the position can be found.

The testing current is limited by any auxiliary resistance, but should be comparatively high so as to get an appreciable reading on the voltmeter, one terminal of which is permanently connected to the auxiliary bus-bar, the other being put to the far end of the feeder to be tested by means of a pilot wire laid for the purpose. The cost of these pilot wires is the chief objection to this method of testing, but if they are put in at the same time as the other cables, the time saved should soon pay for this; one such pilot wire is necessary for each terminus, at which places they are connected to the trolley wires, preferably through fuses.

The arrangements in the station depend on whether the mains are connected to one another outside or not, It is usual that they are not; then, should a "short" occur, it will only affect the one particular section that it is on. The connections for testing such a tramway as is shown in Fig. 91, are given in Fig. 92, by which it will be seen that all of the four feeders are brought to ammeters, and these are connected to the hinges of single pole change-over switches. The ordinary working position of these switches is on the upper contacts. The feeders are then connected through circuit breakers direct to the positive bus-bar, but if a switch is changed over to the bottom contact, that feeder will then be connected to the positive bus-bar, through an auxiliary resistance A R, which, if there be a "short circuit" on the feeder, will keep the current down to a reasonable figure.

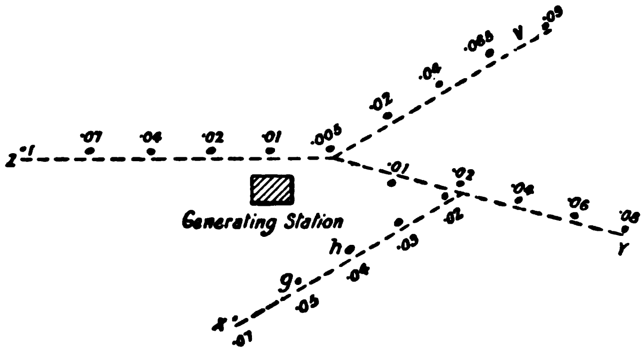


Fig. 91.

It is advisable, as already stated, that this current should be large so as to get a distinct reading on the voltmeter, but if too large it is liable to do harm in the way of burning through a trolley wire or destroying a length of cable; 50 to 100 amperes, however, should be safe enough. Should the mains be connected outside the station, it will only be necessary to have a change-over switch for the feeder that is connected to the trolley wires at the nearest point to the station, the other feeders having ordinary single-pole switches, which must be opened during the testing.

A map is made out to a large scale of the tramway lines and feeders, and the resistances of the latter are marked at all points where they alter in sectional area, and at junctions, such as feeder pillars, etc. This map should be framed and hung in a handy position for reference. In noting the resistances, care should be taken that there are no loose connections in the section pillars to heat and cause the resistance to vary.

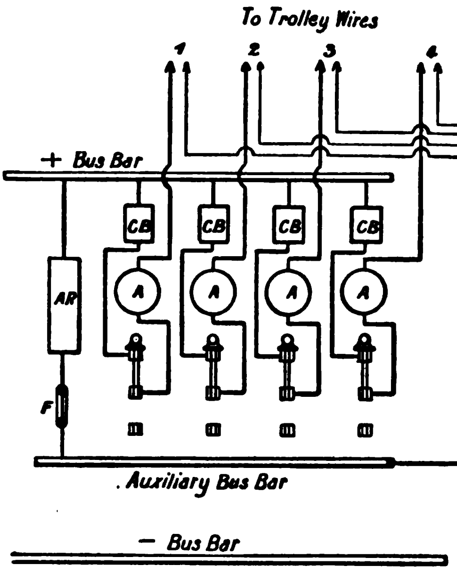


Fig. 92.

A good way to guard against this is to take the resistance of each feeder or section before the cars start running in the morning, and again after the last car has come in at night. The latter result will of course be a little higher than the former, and if the difference is considerable, there is undue heating somewhere, which must be remedied before finally filling in the resistances on the chart.

When a fault occurs the switch of that section is put on the bottom contact, the low-reading voltmeter marked V in Fig. 92 is put between the far end of the feeder and the auxiliary bus-bar, by means of the small multiple-way switch S, thus showing the drop in volts along the feeder (and the trolley wires if they are connected in parallel with the feeder) to the fault; this drop is divided by the value of the current shown on the feeder ammeter, and the map is then consulted to find the position of the fault.

Thus, suppose the ratio $\frac{E}{C}$ or the resistance is found to be ·045, it is evident by the map (Fig. 91), if the fault is on the feeder running to x that it is between h and g, and further it is $\frac{\cdot045 - \cdot04}{\cdot05 - \cdot04}$, or half of the distance from h to g. Even though the trolley wires and the feeders are connected in parallel the fault will always be $\frac{y}{x}$ of the distance between the two section pillars, provided that all three conductors remain unbroken, or if broken, that both ends at the fracture make contact with earth, where x is the resistance from one section pillar to the next (the fault being known to be between these two), and y the ratio $\frac{E}{C}$ found by testing, less the resistance to the section pillar nearer the station. This will be seen by referring to Fig. 93, which represents two trolley wires and the feeder between two section pillars marked P and Q. Let the resistance of any two of these three conductors be r_1, and the resistance of the third be r_2.

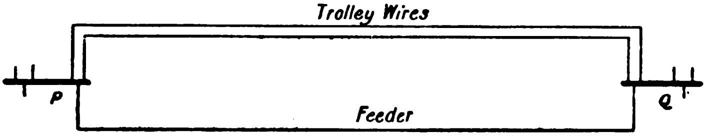


FIG. 93.

The testing current of C amperes is run from P to Q, giving a volts drop between these two points. A fault will be assumed on the third conductor, and its resistance from Q, the further section pillar, to the fault r_3; the current in the first instance flowing along the two wires or a wire and the feeder will be—

$$c \frac{r_2}{r_1 + r_2}.$$

Then

$$a = r_1 c \frac{r_2}{r_1 + r_2};$$

but

$$x = \frac{a}{c};$$

$$\therefore \quad x = r_1 \frac{r_2}{r_1 + r_2}.$$

When testing with a fault on, the current is run from P to the fault, and its value through the two conductors will be

$$c\,\frac{r_2 - r_3}{r_1 + r_2},$$

and if the drop in volts from P to Q is b, then

$$b = r_1\,c\,\frac{r_2 - r_3}{r_1 + r_2},$$

but

$$y = \frac{b}{c};$$

$$\therefore \qquad y = r_1\frac{r_2 - r_3}{r_1 + r_2}.$$

From these results,

$$\frac{y}{x} = \frac{r_2 - r_3}{r_2}.$$

This will represent the fraction of the conductor's length that the fault is from P, as it is of the same section from P to Q. The current in the second case need not be the same as the first, for should it vary the value of b will vary in proportion, and the ratio $\frac{b}{c}$ or y will remain constant.

A similar method of testing is to take the drop in volts on the rails instead of on the feeders; the results would not be so accurate, as the current may flow along a water or gas pipe some distance before it enters the rails, but they should be very useful, and could be applied to most existing tramways without running any extra pilot wires, as there will already be wires run to each terminus and connected to the rails for the Board of Trade recording instruments.

The arrangements in the station will be the same as in Fig. 92, except that the testing voltmeter is connected to the negative instead of the auxiliary bus-bar. It would be necessary, however, when testing, to open all the feeder switches, closing only the one connected to the feeder with the fault on it, downwards; the current from the cars on the other sections, if left on, would also return by the rails and make the results erratic. Whether the rails or feeders are used, the resistances to the various points are best found by experiment; this 'can be done by temporarily connecting the trolley wires to the rails, at these places, one at a time, noting the current and taking the drop in volts. This, of course, could not be done while the traffic was running.

The attainment of the maximum revenue return with a minimum of expenditure is, or should be, the object of every corporation and general manager. This object can only be attained by making a careful and systematic study of the various departments, officials, etc.; catering for the greatest possible passenger traffic (due consideration always being given to the safety of the public), and conducting the management and business on a good, sound commercial basis.

As regards the officials and staff, the general manager himself should be a man of wide commercial experience, should possess good executive ability, be a master of detail, be able to judge the capabilities of his staff, have some legal knowledge, and should possess the important faculty of combining judgment, tact and diplomacy, not only in the handling of his staff of officials, and the management of his tramways, but in the more delicate matter of dealing with complaints, accidents, etc.

The corporation or company should provide him with an efficient staff to carry out his responsible work, and always endeavour to get the best men possible, who should be specialists in their several departments.

In reference to his right-hand man, viz. the traffic superintendent, he should be a man well versed in the technicalities of his work, be well used to the handling and control of men, and be able at all times to successfully cope with any increased demands for traffic (which from time to time take place) providing he has the labour and rolling-stock placed at his disposal.

The car shed superintendent should not only be a good practical man, but be well versed technically in the construction and testing of motors, controllers and all accessories on the car, and thoroughly understand the rolling stock in general.

There should also be an overhead wire and construction superintendent to thoroughly inspect and maintain in good efficient order all wires, etc., and be able to competently superintend any extensions which may be required. The permanent way ought to be periodically inspected.

As regards small corporation tramway systems, it is sometimes economical to obtain men who are fully competent to fulfil a combination of some of the duties of more than one department, but in the case of large corporation tramway systems, it is most advisable and economical to obtain competent specialists in their several departments.

The motor men should be very well instructed in regard to the smooth working and running of their cars, more especially when starting and stopping; this should be done gradually, which prevents undue strain on the motors and the cars themselves, also the unpleasant jolting of the passengers.

The rolling stock should be periodically overhauled, inspected, cleaned and greased (where required); the brushes and the sliding contacts on the controller barrel should be kept clean, and good metallic clean contact at even pressure be maintained between the brushes and contacts. The motor bearings and gearing should be well lubricated, and the armature commutator kept smooth and clean and the brushes nicely adjusted, and suspension mechanism kept in good order; all cable and wire connections should be in good contact (both electrically and mechanically). Loose connections cause faults and undue heating. The sand boxes and sanding pipes should be kept dry and clean, the hand-brakes and pull rods and chains should work freely and the bearings should be well greased, and the emergency brake be in good order; the same remarks apply to the electrical appliances, etc., such as trolley pole and wheel, circuit breaker, lightning arresters, fuse blocks, switches, lamps, etc.

With such systematic inspection, etc., the life of the car and its equipment is increased, and the cost of maintenance is kept low. As before stated, the permanent way should be periodically inspected, more especially at crossings, turnouts and switches, frogs, etc. The automatic tongues and tongue boxes should be kept clean and working freely, rail joints should be often inspected to see that they are not vibrating loose; it is highly important that the rail grooves should be kept as clean and free from gravel, sand, stones and mud as possible; it must not be forgotten that the tractive force or resistance to traction is kept low by such means, which of course means less power consumed in working the car. The track should be periodically gauged to see that it keeps true. By such inspection, etc. the life of the truck and car wheels is increased, the power consumed kept to its lowest, and the maintenance expenses kept low.

The overhead equipment should also be periodically inspected, the poles should be kept well painted, as this prevents rusting; every ear should be examined to see if the wire is worn at the lip, and that the insulating bolt is in good order. Span wires, guard wires, flexible suspensions and nozzles should be examined for broken strands and rust. All nozzles, turnbuckles, mechanical frogs and their pull gear should be kept well greased. Cracks should be looked for in globe strains and other insulators. Section insulators should be examined for wear, and feeder cables should not have worked loose at the section insulators, or have the insulation worn off at the point where they come through the pole.

The fact must not be lost sight of, that a certain percentage of the revenue receipts is required for maintenance expenses, and the great object should be to keep this expense to the lowest possible limit. This can only be attained first by installing a good sound equipment from beginning to end, and second, by employing competent officials, who give the different sections a thorough systematic inspection and overhauling; this avoids accidents from neglect, and keeps the equipment in smooth and efficient working order.

A word or so here will not be out of place regarding the size of tramcars to be adopted from a commercial point of view. As regards this choice of cars, there are different opinions. Some tramway engineers and managers are in favour of the small type, and others are in favour of the large type of cars. Neither type, taken separately, fulfils the ideal, under average local conditions: generally a combination of the large and small type is more economical.

For example, supposing we take seaside resorts. In winter, when the traffic is comparatively small, then the small type of car is more economical, because they require less power to drive them. In summer the large type of car is the more economical because they carry the most passengers. The fact must not be lost sight of that, whereas the large type of cars require more power to drive them than the small ones, still, at the same time the labour cost of running them, i.e. the motor man and the conductor, is exactly the same. Under some special conditions, however, in the case of very large cars at busy times, there is sometimes a boy in addition to assist the conductor in his duties.

Therefore, in winter, it would be false economy, under the above conditions, to run large cars comparatively empty of passengers, since there would be an excess of energy used for no useful purpose; and in summer it would be false economy to run a very quick service of small cars to cope with the large passenger traffic, because by so doing you have a big capital outlay on a large number of cars, comparatively increased labour expenses, and increased depreciation and maintenance expenses.

Again, in large manufacturing or business cities, generally a combination of the large and small type of cars is the most economical, for the very obvious reason that at certain hours of the day, viz. at morning, noon and evening, there is generally a large passenger traffic which has to be met by having the large cars; again, during certain other hours of the day the passenger traffic is comparatively small, and then the small cars are the most economical. To state the proposition in a few words, there are the hours of large traffic demands suitable for the large cars, and the hours of small traffic demands suitable for the small cars—assuming, of course, that the time service of the cars is the same in each case. The question then resolves itself into what is the most economical method to follow to attain the maximum revenue returns with minimum capital outlay and expenditure, because this question affects the whole question of the power station design, size of feeders, number, size and cost of cars, extent of the staff, maintenance, labour, etc. The answer to this is to judge the local conditions, obtain some reliable data of the probable passenger traffic (from generally already existing conditions), and the probable increase;

and from these data to so proportion the combination of the number of each type of car, large and small, that with the agreed-upon time service you can carry the full complement of passengers at all hours of the day, with the minimum outlay of capital, labour, consumption of power and maintenance expenses. In conclusion, the author believes there are very great possibilities in the development of light railways in the near future, also the carriage of parcels and goods traffic by electric tramway and railway systems.

INDEX.

ACTION, grinding, between flanges of wheels, 3
Advantages of different sizes of cars, 109
— of dividing line into sections, 69
— of pitch over cement grouting, 43
Anchor sole plates, 30, 31
Anchoring of trolley wire, 70, 71
— beams, 21
— ear, 80, 81
— poles, 62
Anchors, setting of, 71, 72
Angles, intersection of, 2
Arcing, 74
Armature, heating of motor, 7
Australian woods, 41

" BADGER " mechanical ear, 81, 82
Ballast, track, 37
Ballasted road bed, 38
Bar, tie, 25
Base plate, 65
Bed, road foundation, 21
— cushion for wood blocks, 42
Blocks, wood, fibre cut vertical, 42
Bonding, double and cross, distance apart, 35
— objects effected by good, 36
— of rails, 32
Bonds, carrying capacity, 36
— gauge, 36
Bonds, size, 35
Bournemouth, pavement used, 47
— tramways, particulars of, 88
Bowker rail bond, flexible, 34, 35
Bracket arm hanger, 79, 80
Brackets, side arm, 54
Branch feeders, 69
Branch-off, single track right-hand, 2
Brighton, anchor sole plates, 30, 31
— tramways, particulars of, 86, 87
Brooklyn strain insulator, 83
Buckling of rail flanges, 23

CANTING of rails, 23
Capetown tramways, particulars of, 89
Car, wheel-base of electric, 3
Cardiff tramways, particulars of, 89, 90
Car-house curves, 12, 15
Carriage of parcels and goods, 111
Car shed superintendent, 106
Cast-iron chairs, 37
Catenary, 75
Centre line construction, 51
Chart test, 99
Choice of overhead materials, 49
— of size of tramcars, 109
Clamp for soldering ear, 73
Clearance curve, 2
Combination of sizes of cars, advantages of, 110, 111

Complicated layouts, 1
Concrete, composition of, 25
— foundation, 25
Conditions which cover size of cars, 109, 110
Connecting curve with crossing, 11, 12
Constant for elevation of rails, 16
Constants, table of, 17
Construction and expansion of rails, 16
— centre and side line, 51, 52
— single track, 2
Copper rail bonds, 32
Corporation tramways, management of, 105, 106, 107
— — Bournemouth, 88
— — Brighton, 86, 87
— — Cardiff, 89, 90
— — East Ham, 94, 95
— — Glasgow, 93, 94
— — Lancaster, 87, 88
— — London United, 95, 96, 97
— — Manchester, 84, 85, 86
— — Portsmouth, 90, 91
— — Salford, 91, 92
Cost of wood and iron poles, 55
Creosoted poles, 56
Creosoting wood pavement, 41
Crossings, 81, 82
Cross-ties, dimensions of, 31
Cross or span wires, materials used for, 58
Crossovers, dimensions of, 18, 19
— standard long 13° 41′ frogs, 18
— — 15° frogs, 19
— — short 17° frogs, 18
Cross wire construction for double track, 58–60
Curling of rail flanges, 23
Curvature, radius of 3, 6
Curve clearance, 2
Curves, car-house and gauntlet track, 12, 15
— lay out of, 3
— radius of, 3
Curves, sharp, 3
Cushion bed for wood paving, 42
— — sand, 40
Cutting-in of rails, 23

Depth and width of track bed, 26
Diagrams of test connections, 100, 101
Diamond turnout, 3, 4, 9
Different widths of streets, 2
Dimensions of standard crossovers, 18, 19
Dip and sag, effect of temperature on, 75
— — — of wire, 75
Distance between poles, 62
Dog-toothing, 43, 44
Double pull-off, 80
— track, 2
— — distance apart of, 1
— — plain curve, 11, 13
— — R.H. branch off, 11, 14

Ear, 79
— bodies, location, 72
Earthing of pole, 75
East Ham tramways, particulars of, 94, 95
Electric car, wheel-base of, 3
Electrical circuit, 49, 50
Electrolysis of pipes, 36
Elevation of outside rail, 16
Embedding sleepers in concrete, 28
Expansion and contraction of rails, 16
— joint, 43
— or swelling of wood, 42, 43

Factor, power, 10
Feeder ear, 81, 82
— pillars, 101
Feeders, 68, 69
— testing, 100

Financial considerations in equipment of cars, 109, 110
Fish-plate holes, 29
— weight of, 31
Flexible rail bond, the Bowker, 34, 35
— wheel bases, 20
Formula, Dr. W. G. Rhodes', for track curves and wheel-base of trucks, 6, 7
— for elevation of outside rail, 16
— for tests, 103, 104
Foundation or foot plate, 63
— concrete, 25, 26
— road bed, 21
Frogs, 10°, 8, 9
— 13°-41′, 8
— 9°, 9
— locating and setting of, 61
— or switches, 60
— placing of, 60, 61
— right-hand, left-hand, Y, three-way, 81, 82
— supporting of, 60, 61

GALVANIZED wires, disadvantage of, 58
Gauge of track, 1
— variation, 1
Gauntlet track curves, 12, 15
General manager, qualifications of, 105, 106
Glasgow tramways, particulars of, 93, 94
Globe insulators, 83
Gradients, long and steep, 10
— practical limit of, 7
Great Yarmouth Tramways, 92
Grinding action, 3
Grooves, prevent filling up of rail, 47
— width of rail, 6–7
Grouting, 42
— bituminous and cement, 40
— pitch and cement, 43, 44
Guarding against heating error, 102
Guard wires, distance apart of, 66, 67
— — material and size of, 58
— — breaking of, 68

HANGER, 79
Heating of motor armature, 7
Heaviness of street traffic, 29
Height of trolley wire, 75
Holes, depth of, 63

INCREASE and decrease of temperature, 16
Insulated turnbuckle, 83
Insulating terminal clamp, 82
Insulator section, 78, 79
Intersection of angles, 2
Iron slings, 71
Isle of Thanet Tramways, particulars of, 95

JARRAH wood for paving, 41
Jim crow or screw jack, 32
Joints between blocks, 42
Joint-spacing, 14
Jolting and vibration, 10
Jumping the trolley wire, 59, 60

KARRI wood, 41

LABOUR cost of running cars, 109
Lancaster, anchor sole plates, 30, 32, 33
— Tramways, particulars of, 87, 88
Laws for strain, tension, etc., 75–77
Laying out of curves, 3
— — of permanent way, 1

Layouts, complicated, 1
Left-hand end, 8, 9
— — frog, 81, 82
— — throw-over turnout, 3, 5
Length and weight of rails, 29
— between points of support, 75
— of ears, 74
— of turnouts, 12, 13
Light railway, 1
— railway construction, 55
Limit of gradients, 7
— of gradient for wood paving, 45
Limits of radii, 19
— of wheel-base, 3
Line, distance apart of sections, 68
Localising faults on tramways, 99–105
Locating position of frogs, 61
London United Tramways, particulars of, 95–97
Loose joints due to vibration, 21

Maintenance cost kept low, 107
— expenses, 108, 109
— of rolling stock, 10
— of tramways, etc., 106–108
Management of tramways, 105–107
Manchester Tramways, particulars of, 84–86
Map for tests, 101
Mate, 8, 9
Maximum revenue return, 105
Methods of staying and strutting, 54–56
Minimum of expenditure, 105
— outlay of capital, 111
Motor men, instruction of, 107

Outer rail, raising of, 20
Overhead trolley wire material, 56
— equipment materials, 49
— wire superintendent, 106

Parabola, 75
Paving, Jarrah and Karri woods, 41
— material, selection of, 38
— — squeegeed, 45, 46
Pavement, advantages of granite, 39
— depth, length and breadth, 39
— wood blocks, 28
Plain curve, single track, 2
Permanent way inspection, etc., 107, 108
— — laying out, 1
Pilot wires, 99, 104
Plain Y, 10
Plastic rail bond, 34
Plate for pole bottom, 63
Plates, tie, 23, 24
Poles, distance apart, 62
— planting of, 63, 64
— rake of, 64
— rearing of, 64
— setting of, 63, 64
Portable rail carriage, 29, 30
Possibilities in development of light railways, 111
Poles, iron, 56, 57
— wood and iron, 54
Polygon, 58
Portsmouth Tramways, particulars of, 90, 91
Power factor, 10
Practical limits of gradients, 7
— — of wheel-base, 3
Preparation of setts, 40
"Proud" with rails, 45

Racking, 42
Radii of curvature, 8, 9
Radius, effects of different limits of, 19
— of curvature, 3, 6
Rail bed foundation, concrete, 24, 25
— bonding, 32, 33
— bonds, Bowker flexible, 34, 35
— — Chicago, 34
— — Columbia, 34
— — Neptune, 34

Rail carriage, portable, 29, 30
— effects of sand on, 19
— filling, 36
— flanges, buckling and curling of, 23
— grooves to prevent filling, 47
— — width of, 6, 7
Rails, elevation of, 16
— expansion and contraction, 16
— exposed and partially exposed, 16
— kinks in, 32
— length and weight of, 29
— levelling, setting and ramming, 32
— raising of outer, 20
— rolling or canting of, 23
— spreading of, 23
— tilting of, 21
— tread of, 45, 46
— undulation of, 21
— weight of, 13
— welding, 36
Raising of outer rail, 20
Rake of poles, 64
Rearing of poles, 64
Relation between wheel-base and radius of curvature, 7
Resistance to traction, 19
Return circuit, 50
— — through the rails, 33
Rhodes, Dr. W. G., formula connecting curves and wheel base, 6, 7
Right-hand branch-off single track, 2
— — frog, 81, 82
— — end, 8, 9
— — throw-over turnout, 3, 5
Road bed foundation, 21
Rolling stock, overhauling, 107
Rule for rake of poles, 64

Safeguard of moving mass, 20
Sag and dip of wire, 75
— in inches, table of, 78
Salford Tramways, particulars of, 91, 92
Sand, effects of, on rails, 19
Screw jack or jim crow, 32
Section insulator, 78, 79
Sections of line, 68
Setting of anchors, 71, 72
— of rails, 31, 32
— of frogs, 61
Sharp curves, 3
Shingle, 40
Side arm brackets, 54
— line construction, 51, 52
— pole construction, 53
— turnout, 3, 4, 8, 9
Silicon-bronze wire, 56
— — advantages of, 58
Single pull-off, 80
— track construction, 2
— — plain curve, 2
— — right-hand branch-off, 2
Size of span wires, 65
Sizes of pavement, 39
— of tramcars, 109
Skin strength of wire, 74
Sleepers, cutting in, 23
— effects of moisture, 23
— on ties, wooden, 24
— wooden, 22, 23
Slings of iron, 71
Soldering of wire to ear, 73
Sole-plates, 21, 30, 31
— steel, 31
Spacing of rail joints, 14
Span wire construction, 53
— or cross wires, materials used for, 58
— wires, grip, 79
— — size of, 65
Specialists on tramways, 107
Specification of paving, 40, 41
Speeds, table of, 17
Splicing ear, 81, 82
Spring bridge insulator, 80
Standard crossover 15° frog, 19
— long crossover, 18

Standard short crossover, 18
Staying and strutting of wood poles, 54–56
Steel girder type of track, 13
— sole plates, 31
Straight line insulator, 79–81
Strain of trolley wire, 51, 52
— on motors, 10
Straining clamps, 71, 82
Street boxes and switches, 69
— paving tools, 48
— traffic, heaviness of, 29
Streets, different widths, 2
Switch, tongue, 3, 4, 5, 8, 9
Switches and street boxes, 69
System of light railway traction, 1

TABLE of constants, 17
— of sag in inches, 78
— of speeds, 17
— of tensions, 78
Temperature, effects of, on rails, 16
Tensile strain, calculation of, 75–77
Tension in pounds, table of, 78
Tensioning of wires, 66
Testing of tramways, 99–105
Three-part Y, 11
Through Y, 11
Through-connected Y, 11
Tie-bar, 25
Tie-bars, distance apart, 31
Tie-plate, 23, 24
Tie plates, 24
Ties, wooden, 22, 23
— cutting in of rails, 23
— moisture effects, 23
Tilting of rails, 21
Tongue switch, 3, 4, 5, 8–12
Tower wagon, 71
Track, ballasting, 37
— bed, depth and width of, 26
— curves and wheel base formula, Dr. Rhodes', 6, 7
— double, 2
Track, double, distance apart of, 1
— gauge of, 1
— rail, steel girder type, 13
— — weight of, 13
Traffic superintendent, duties of, 106
Tramcars, choice of sizes, 109
Traction resistance, 19
— system, 1
Tractive force kept low, 108
Tread of rails, 45, 46
Trolley line, height of, 75
— wheel, wear of, 52
— wire curves, 59, 60
— — composition of, 56
— — size of, 57
Turnbuckles, 52, 74
Turnouts, diamond, 3
— left-hand throw-over, 3
— right-hand throw-over, 3
— side, 3
Twist or torsion of wire, 73

UNDERGROUND system of feeders, 69

Wagon tower, 71
Wallasey Tramways, particulars of, 92, 93
Wear of trolley wire, 57
— — — wheel, 52
— — wood blocks, 42
Weight and length of rails, 29
— of track rail, 13
Wheel base of electric car, 3
— — practical limits of, 3
Wheel-bases, flexible, 20
— — and track curve, Dr. Rhodes' formula, 6, 7
Width and depth of track bed, 26
— of grooves, 6, 7
Widths of different streets, 2
Wire, hard drawn copper and silicon-bronze, 56
Wires, guard, 66, 67
— tensioning of, 66

Wood blocks, wear of, 42
— paving insanitary, 45
— poles, standard shapes, 56
— — staying and strutting, 54–56
Wooden block pavement, 28
— sleepers or ties, 22, 23, 24
Wooden sleepers embedded in concrete, 28
Woods, Australian, 41
— creosoting of, 41
— Jarrah, 41
— Karri, 41

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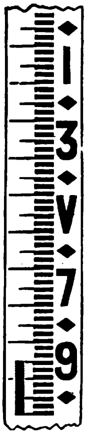

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